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FOREWORD

A sustainable world means working together to create prosperity for all. ... Even when early innovations start to succeed, it is not uncommon to see growing ...

/Jacqueline Novogratz, founder and CEO of Acumen Fund, 2011/

Conference “Rural Development 2013: Innovation and Sustainability” is an international event designed to bring together key stakeholders involved in agricultural and food systems, natural resources and rural development research for discussion on the most important issues impacting our efforts to address the Challenges of Tomorrow. The importance of collaborating internationally relies upon the communication and sharing of research results, plans, resources and lessons learned by all international stakeholders.

Rural development originates from combining innovatively a wide range of different and often, refigured resources, which consequently flow into a set of new activities, interactions, transactions and networks. Only through a successful mix of technological, social, organizational and institutional elements, and emerges through stakeholder interaction and learning Innovation occurs. Therefore, the 6th international conference of Rural Development is orientated to innovations and sustainability.

Innovation – the process by means of which social and economic needs are met with new ideas and new products, services or business and organizational models are created; they are successfully introduced into existing markets or are capable of creating new markets. Innovation is a key factor, as in most developed countries it has long been the main engine for the economic growth, enabling achievement of high business efficiency and profitability, and rapidly improving quality of life.

Sustainable growth means building a resource efficient, sustainable and competitive economy, exploiting leadership in the race to develop new processes and technologies, including green technologies and bio-based economics, using the EU-scale and foreign networks. Such an approach will help to prosper in a low-carbon, resource constrained world while preventing environmental degradation, biodiversity loss and unsustainable use of resources. It will also underpin economic, social and territorial cohesion.

It is a great pleasure for us to welcome at our conference the scientists from our neighbouring countries and those coming from Belgium, the Czech Republic, Estonia, Finland, Germany, Hungary, India, Ireland, Italy, Kazakhstan, Latvia, Lebanon, the Netherlands, Poland, Romania, Russia, Spain, Turkey, the Ukraine, the United Kingdom, the United States and other countries.

All the participants will be awarded the possibility to express their attitudes towards the scientific issues related to the Food Safety and Security, Engineering and Environment of Biosystems, Multifunctional Approach to Sustainable Use of Natural Resources, Social Innovations of Regional Rural Development Future and Present Policy of Agriculture and Rural Development.

May this conference be a useful step in meeting the challenges faced by Agricultural, Food system and rural communities. Proceedings of the International Scientific conference “Rural Development1st” (ISSN 1822-3230 (print), ISSN 2345-0916 (online)) have been published periodically every two years since 2003. The proceedings are indexed and abstracted in the international databases: Thomson Reuters ISI Web of Science (since 2005) and Academic Search Complete via EBSCO (since 2009). The research papers meet the requirements of editorial board and are reviewed by two reviewers under single-blind refereeing process.

The editorial board of the proceedings “Rural Development 2013: Innovations and Sustainability” hope that the scientific ideas presented in the research papers are meaningful not only for the researchers in the fields of agriculture and rural development, but also for the students, politicians and decision makers in the EU, national, regional, local organizations of agriculture and rural development. These ideas will promote constructive debate and search for new solutions, sharing the experience and will encourage further cooperation in and sustainability of rural areas development.

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I.
Engineering and Environment of Biosystems
Resistance of Corn Ears and Grains of Different Maturity to Quasi-Static Load

Sandra Adomavičienė, Dainius Steponavičius, Anicetas Strakšas, Kęstutis Romanèkas, Laimis Bauša
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Abstract

Corn Zea mays L. is among the most remarkable cereal species, which has great importance in the human diet and animal feed in many parts of the world. Corn yield from one hectare can be from 50 to 70 tons of green mass or from 6 to 10 tons of grain. Corn for grain can be harvested using various technologies, provided the grains in ears are in physiological stage of maturity. Awareness of apparent properties such as rupture force, rupture energy etc. of agricultural seeds is important for predicting load-deformation behaviour, and must be taken into account when designing specific processing machines. This study was carried out with the aim to determine the physical and mechanical properties corn grains and corn ears during their different physiological maturity stages. The study of mechanical properties of corn grains and ears was performed applying quasi-static loads using Instron-5960. Corn ear deflection was tested applying different distances between the support beams: 60 mm and 120 mm. Corn ear rupture force decreases when the distance between the supports is increased. Grains were applied load at three different orientations: over the length, over the width and over the thickness. A single grain was placed between two parallel plates and gradually compressed while simultaneously recording the force and the corresponding deformation that occurred until the grain ruptured. At this point the force suddenly decreased, while deformation continued. In most cases, the initial portion of grain load-deformation curve was more or less linear up to certain points of deformation beyond which it became non-linear. The observed bioyield point represents the yield point in biological materials. This is an indication of initial cell rupture in the cellular structure of material. The results showed that provided moisture content was reducing from 50.94±1.64% to 36.21±0.52%, the maximum corn grain rupture force increased from 91.54±16.75 N to 200.67±18.43 N.

Key words: corn, corn ears, quasi-static load, bioyield point, rupture force

Introduction

In human nutrition, corn has been an important component since 4500 B.C. This is one of the most rapidly energy-accumulating agricultural plants, which later may be used for various purposes (Tarighi et al., 2011). Automation of crop yield harvesting and post-harvest processing result in increasing cultivated corn fields. However, the quality issue of harvested, transported, and stored corn persist. For example, during harvesting period, when moisture level of corn is high and meteorological conditions are unfavourable; grain damage rate is usually high, which results in high losses. This loss is usually caused by operating parts of agricultural machinery. Grain loss and damage rate mostly depend on machinery construction and technological parameters as well as maintenance of the machinery, also the field where crops are cultivated, meteorological conditions, and morphological, physical and mechanical properties of the yield (Anazodo et al., 1981; Spokas and Steponavičius, 2011).

The size, shape, and physical-mechanical properties of cereal grains should be taken into account when designing harvesting, cleaning, sorting and threshing machinery (Seifi and Alimardani, 2010; Mohamed, 2009; Heidarbeigi, 2008). It has been claimed that being aware of corn ear physical-mechanical properties, and aerodynamic properties of grains, helps defining technological parameters of threshing apparatus and guidelines for construction improvement more precisely (Spokas et al., 2007). Physical-mechanical properties of corn grains and ears depend on corn variety (Sandhu et al., 2007, Szymanek et al., 2008), harvesting time, and moisture level (Anazodo et al., 1981; Petkevičius et al., 2012; Dorsey-Redding et al., 1991). It has been established that breaking dry corn ear requires approximately 20% higher force than breaking of high-moisture corn ear. High-moisture corn ears are more elastic, therefore they require almost twice larger deflection for breaking compared to dry corn ears (Čenys and Steponavičius, 2010). In later stages of maturity, grain moisture level reduces, and certain properties change. For example, dry grains (9.3%) are characterized by higher elasticity than high-moisture grains (22.5%), which are characterized by higher plasticity (Ponce-García et al., 2008).

Aim of the research is to determine the impact of moisture level, maturity stage and direction of compression force for corn ear and grain resistance to quasi-static load.

Materials and methods

Subject of this research was early hybrid variety Tango corn (FAO 210) (derived in Germany, Südweststaat/Saaten-Union seed farm) ears and grains. Corn was planted on 2 May 2012 in A. Stulginskis University experimental station. Scientific experimental research was carried out during September-October of the same year, using physical-mechanical testing system Instron 5960 (Figure 1) twice a week in the Agricultural machinery research Laboratory. The machine is installed the software Bluehill.

Biometrical indicators. During the research, corn ear biometrical indicators were first determined. Corn ears were weighted in the laboratory, measuring their length, diameter and determining the number of grain vertical rows and horizontal rings, total number of grains on one ear, and weight of 1000 grains. Also measured were the length, diameter and weight of pith. Moisture levels of leaves, grains, and piths were determined by drying them in a 105 °C temperature drying chamber until air-dry mass is achieved. Moisture percentage was calculated based on the difference in the masses of wet and dried grains.
Grain crushing test. This test is performed by crushing a grain by a 4.7 mm rod, which moves at the speed of 20 mm·min$^{-1}$. This load may be considered as quasi-static since inertia impact is not significant. During the test, a grain was put on a sample plate 3 which is attached to the stand 4 (Figure 1), and crushed by a rod 2 until rupture. The test was performed with grains of different maturity stage. Also observed during the test were variation of grain kernel rupture force $F_1$ (biyield point), maximum force required for grain rupture $F_{\text{max}}$ (rupture force), marginal shift (deflection) $a_p$ and Young’s (elasticity) modulus $E$ depending on maturity stage.

Compression tests were performed with three directions of grain crushing force: applying force coinciding with the longitudinal axis of the grain (along the grain); applying force to the grain placed on the plate at its largest area – in the direction of thickness; and applying force to the grain placed on the plate laterally (Figure 2).

**Figure 1.** Material properties testing machine *Instron 5960*:
1 – force sensor, 2 – rod, 3 – sample plate, 4 – stand, 5 – frame; 6 – control panel; 7 – limit switch

**Figure 2.** Directions of grain compression force $F$: a) along the grain, b) through the thickest part, c) through the width

**Corn ear crushing along their length.** Tests were performed during September-October, twice a week. For the test, corn ears of similar length and width were selected with similar front and back parts (of similar diameter). The selected corn ears were divided into three parts every 50 mm (Figure 3). During the tests, every part of a corn ear was pressed in the radial direction with a special crushing tip registering crushing force and tip shift.

**Figure 3.** Corn ear divided into three parts: front part, middle part, and end part
Corn ear bending test. This test was performed using the machine Instron 5960 where corn ear was placed on special supports (Figure 4). During bending test, different clearances between the support beams the ear was placed on were applied: 60 mm and 120 mm. During the research, corn ear was bent until it crashed. Using special measuring equipment, the force required for braking corn ear was determined. Moreover, the shift of a tip pressing down the corn ear until it ruptured was also registered (marginal corn ear deformation). Corn ear was loosely placed on support beams (unattached), and as a result, there were no embedding into the corn ear. Corn ears were researched during their ripening, September-October.

For bending tests (distance between support beams \( L = 60 \) mm), corn ears 181±3 mm in length, and 45±1 mm in diameter were selected, and for tests when \( L = 120 \) mm, corn ears selected were 185±2 mm long, and 45±1 mm in diameter.

![Figure 4. Corn ear bending: \( F \) – force applied, \( L \) – distance between support beans; a) test scheme, b) general picture](image)

Statistical evaluation of research data. Every test was repeated for five times. Experimental data has been processed in accordance with the statistical methods. The average value of the records and their confidence intervals (\( P = 0.05 \)) are given (Olsson et al., 2000). To establish the correlation of two factors, the curvilinear correlation coefficient \( R^2 \) is calculated. Fisher’s criterion is used to find the curvilinear correlation of two factors. Regression equations are used to calculate the direction and size of the factor correlation.

Results and discussion

Grain crushing test. Based on the tests it has been established that during the ripening period of corn ears from early September till early November, grain moisture level reduced from 50.94±1.64% to 36.21±0.52%; moisture level in corn ear pith – from 66.65±5.92% to 54.84±4.53%; and leaves covering corn ears – from 68.68±1.65% to 46.52±3.10%.

During the process of grain crushing, the graph showed two significant peaks: grain kernel rupture force \( F_1 \) (bioyield point), and maximum rupture force \( F_{\text{max}} \) required for grain fragmentation (Figure 5). After grain crushing tests, it has been determined that in the progress of grain ripening with moisture level reducing, grain kernel rupture force \( F_1 \) and force required for grain fragmentation \( F_{\text{max}} \) increase (Figure 6).

![Figure 5. Typical variation of force \( F \) during grain crushing along its axis](image)
While crushing grain along the length, the force required for grain crushing $F_{\text{max}}$ increased from $20.40 \pm 0.85$ N (milk stage) to $67.52 \pm 5.46$ N (hard maturity) (Figure 6). While crushing grain along its width, the force required for grain crushing during different stages of maturity increased from $60.21 \pm 4.08$ N (milk stage) to $120.42 \pm 9.38$ N (hard maturity). While crushing grain along its thickness, the mentioned force $F_{\text{max}}$ increased from $91.54 \pm 16.75$ N (milk stage) to $200.67 \pm 18.43$ N (hard maturity).

![Figure 6. Variation of force required for grain crushing $F_{\text{max}}$ (maximum rupture force)](image)

During the research, variation of grain elasticity modulus $E$ during different stages of corn maturity was observed. The highest elasticity modulus was observed while crushing grain along its thickness; it increased from 210.32 MPa to 792.38 MPa during September-October. The lowest elasticity modulus was observed when crushing grain along its length; the modulus $E$ increased from 41.24 MPa to 344.48 MPa. When crushing grain along their width, elasticity modulus increased from 51.56 MPa to 651.11 MPa.

**Corn ear bending test.** Having performed corn ear bending tests it has been established that in the progress of corn ear ripening when moisture level decreases, force required for breaking corn ears increases (Figure 7). Given that distance between bending supports is 60 mm, force required to break corn ear varied from 685.37±34.36 N (milk stage) to 896.57±155.13 N (hard maturity). When distance between bending supports was 120 mm, required force $F_b$ was smaller and varied from 268.82±120.96 N (milk stage grain) to 452.38±75.92 N (hard maturity grain).

![Figure 7. Variation of forces $F_b$ required for breaking a corn ear during different stages of maturity](image)

It has been also determined that marginal deflection until corn ear breaks reduced when maturity progressed (Figure 8). When distance between bending supports was 60 mm, bending until corn ear breaking force was achieved reduced from $15.72 \pm 1.95$ mm (milk stage grain) to $10.16 \pm 1.28$ mm (full maturity grain). When distance between bending supports was 120 mm, deflection $a_b$ reduced from $12.53 \pm 2.37$ mm (milk stage) to $8.97 \pm 0.74$ mm (hard maturity). Distance between supports affected only marginal deflection of corn ears in their milk stage. When bending
wax-ripe and hard maturity corn ears, changing the distance between the supports from 60 mm to 120 mm had no significant effect.

Figure 8. Variation of marginal deflection until corn ear breaking point \( a_b \) during different stages of maturity

Picture 9 shows that when the distance between bending supports is smaller (60 mm), marginal deflection until corn ear breaking point is higher compared to deflection when distance between bending supports is larger (120 mm). Having assessed the results from two-month investigation, linear correlation between the force \( F_b \) and corn ripening time \( d \) was determined. The relationship between deflection \( a_b \) and corn ripening time \( d \) was also linear, however inversely proportional.

Summing up corn ear bending tests, interdependence between force \( F_b \) required for corn ear breaking and deflection \( a_b \) was determined (Figure 10). Therefore, it can be argued that the higher the force required for corn ear breaking, the smaller is the shift of the tool used to achieve it.

Figure 9. Variation of force \( F_b \) and deflection \( a_b \) during different stages of corn ripening:

- Force \( F_b \) when \( L=60 \) mm: \( F_b = 4.11d + 683.7 \); \( R^2=0.81 \)
- Force \( F_b \) when \( L=120 \) mm: \( F_b = 2.36d + 324.7 \); \( R^2=0.62 \)
- Marginal deflection \( a_b \) when \( L=60 \) mm: \( a_b = -0.115d + 14.98 \); \( R^2=0.87 \)
- Marginal deflection \( a_b \) when \( L=120 \) mm: \( a_b = -0.069d + 11.91 \); \( R^2=0.79 \)
Figure 10. Dependence of the force $F_b$ required for breaking corn ear on marginal deflection $a_p$:

- Force $F_b$, when $L=60$ mm: $F_b = -28.78d + 1132.9$; $R^2=0.61$
- Force $F_b$, when $L=120$ mm: $F_b = -34.17d + 732.0$; $R^2=0.78$

Corn ear crushing along their length. The tests of crushing corn ears along their length showed that in the process of corn ripening with the moisture level reducing, the radial force required for corn ear crushing increase (Figure 11). During ripening, from September until the end of October (from milk stage until hard maturity stage), force increased from 1272.86±30.01 N to 2268.49±81.96 N in the front part of corn ear, from 1277.77±61.25 N to 2575.08±80.74 N in the middle part of corn ear, and from 1573.67±50.24 N to 2999.27±76.12 N in the end part.

During the milk stage, variation of the force required for crushing the front part of corn ear was not significant. It was noted that the end part (at the stem) is the most resistant to crushing, a little less resistant was the middle part, and the front part appeared to be the less resistant to crushing.

Having assessed the results of two-month research results, linear correlation between the deformation force $F_{max}$ and corn ripening time $d$ was determined. The relationship between marginal shift $a_p$, and corn ripening time $d$ was also linear, however inversely proportional.

Figure 11. Variation of corn ear deformation radial force

Summing up crushing tests applied to different parts of corn ear (front, middle, and end), interdependence between deformation force $F_{max}$ and marginal shift $a_p$ was determined. Based on the research results it can be argued that the higher force is required for deforming a specific part of corn ear, the smaller is the shift of the tool used to achieve it.
Conclusion

During grain ripening from September till October, moisture level of corn ears reduces from 50.94±1.64% to 36.21±0.52%, and the maximum force required for crushing grains increases from 91.54±16.75 N to 200.67±18.43 N. During ripening, moisture level and elasticity of corn ears reduce, therefore the force required for breaking a corn ear increases and marginal deflection reduces.

Force required for breaking corn ear $F$ depend on the distance between the supports corn ear rests on during deformation. When the distance between the supports is 60 mm, force $F$ reaches 896.6±155.1 N, and when it is 120 mm – 452.4±75.9 N.

References


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Research of Microclimate in Dairy Cattle and Pig Buildings

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Abstract

The experimental investigations were carried out in industrial sheds of calves, meat pigs and cattle sheds of various design in different periods of the year. The correspondence of shed air temperatures and relative humidity to the regulations and the variation of air temperatures and relative humidity in respect of climate conditions outdoor were estimated. In winter the favourable temperatures were maintained in insulated sheds and during summer heat the temperatures were higher by a few degrees than the recommended level. The hottest temperature was in the cold cowshed (by about 10 °C higher than recommended) and the coldest temperature was as low as -14.2 °C during a short period with the outdoor temperatures below -20 °C. The main problem in all sheds was not unfavourable temperatures but high air humidity. In the insulated cattle sheds it was too humid even during the warm period of the year. In uninsulated sheds air humidity increased when outside temperature was below -10 °C and in insulated sheds air humidity already increases when outdoor temperature is below 6–14 °C. From all investigated sheds the air humidity met the regulations best in the pig shed, and in the insulated and semi-insulated cubicle cowsheds. The main reason for unfavourable microclimate is too low ventilation rates. In each shed it is recommended to prepare optimal algorithm for the management of temperature difference variation in sheds and outdoors and according to it to control ventilation rates in sheds.

Introduction

In the process of shed renovation frequently problems related to microclimate arise i.e. how to ventilate the shed intensively, what temperatures to maintain in it. During the last decade uninsulated (cold, outdoor climate) cattle sheds have become popular. Traditional insulated tied cowsheds are being reconstructed into deep bedding and cubicle cowsheds whose outer partitions are uninsulated or only the roof is insulated. The trend of such sheds development was influenced by positive evaluation of uninsulated cowsheds in many countries. Intensive construction of cold cowsheds in Western Europe started in 1985, in Scandinavian countries – in 1990, in Estonia – 1995, and in Lithuania – in 1998. Keeping cows and calves in cold sheds is also expanding in cold regions of the world. (Hilty et al., 2003; Lucenko and Salyga, 2006; Pajumagi et al., 2007). In order to lower construction costs of pig sheds, attempts are also made to insulate only bedding places. Many scientists, who have investigated microclimate in uninsulated sheds (Schneider, 1988; Zhao et al., 2007; Deuker, 1984), agree that methodological problems exist in analysing microclimate in open sheds, as it is difficult to identify ventilation rates accurately (Snell et al., 2003; Teye, 2008). Traditional methods are not suitable for the assessment of ventilation rates in sheds. The best way is to analyse dynamics of air parameters and according to it to assess ventilation effectiveness. From the most fluctuating air parameters (air temperature, relative humidity, air velocity), the temperature is the best index for ventilation assessment (Pajumagi et al., 2008). Properly installed ventilation systems in uninsulated sheds can ensure microclimate within the optimal range during all seasons of the year (Pajumagi et al., 2007). Other scientists (Frederick et al., 20080) observe that microclimate in such sheds is strongly affected by shed design, ambient temperatures, wind and manure removal method. In these sheds it is complicated to analyze air quality and ventilation rates in spring and autumn, as weather temperature, relative humidity and air velocity change rapidly. Problems also arise in these sheds in summer because temperatures are very often above the highest point of 27 °C. Although the air in cold cowsheds is cleaner and concentration of hard particles is lower if compared to pig and fowl sheds (Kaasik and Maasikmets, 2013). Different microclimate factors in them fluctuate within wide range and have negative impact on animal bodies. Animal bodies can adapt to varied temperatures and other microclimate factors but only to certain limits. Very strong and unusual factors reduce body’s resistance, causes deceases, animals become weaker and production decreases.

According to the data of scientific investigation (Sallvik, 1998; Neimann and Tribe, 1987), high temperatures are more hazardous for cattle than low temperatures. With the ambient temperatures as low as −15 °C, a cow milk yield decreases from 0.5 to 2.0 litres per day, whith the ambient temperatures as high as +30 °C, a cow milk yield decreases from 2.0 to 4.0 litres per day. Different opinions exist on optimal air temperatures for a cow. By summarising the results of investigations carried out by different scientists (Bartussek, 1984; Caenegem and Wechsler, 2000; Clark, 1992; Stolpe, 1985), it can be stated that the optimal temperatures for keeping productive cows are from −7 to + 23 °C. These temperatures are suitable for loose cattle. The recommended temperatures for insulated calf, cow, meat cattle sheds are 3–17 °C (Kavolėlis, 2006). The relative air humidity matching the highest temperature limit is 61%. When pigs are kept on deep bedding, the recommended air temperatures in sheds are 8–18 °C and when they are kept in sheds without bedding, the recommended air temperatures are 16–20 °C.

The best way to relate the highest allowed air relative humidity in an insulated shed \( \phi_i \), %, to its temperature is to apply the following regression equation

\[
\phi_i = 95 - 1.5 \ t_i, \\
\]

where

\[ \ t_i \] – air temperature in shed, \( t_i \geq 0 \degree C \).

In order to have healthy and productive animals, optimal microclimate must be ensured in sheds all year round. It is essential to control the most important factors of microclimate air temperatures and humidity, which also influence other factors (ammonia, sulphur hydrogen gas concentrations, etc.). Effective natural or mechanical ventilation systems...
in sheds must be installed which removes polluted air from sheds (also heat excess in summer) and supply clean outdoor air.

The objective of the investigation: to evaluate air temperatures and humidity in the pig shed and cattle sheds of different design and to foresee instruments for the contrll ventilation rates under varions of climate conditions.

Objects and Methods

The experimental investigation was performed under industrial conditions in a calf shed, meat pig shed and in different cowsheds: a half-deep semi-insulated shed, a tied insulated shed, a cubicle cold shed and a cubicle semi-insulated shed (only the roof is insulated). Heifers are kept loose on half-deep bedding in an insulated, brick shed with eaves. A natural, channel type ventilation system was installed. A pig shed, where 80 pigs are kept on deep bedding, is brick and has insulated eaves. A combined ventilation system was installed in it.

The most popular cowshed types in Lithuania were selected for carrying out the investigation. A half-deep cowshed – such solutions are often applied in renovating old, tied, not very big cowsheds. 140 cows are kept in this cowshed whose walls are built from reinforced concrete blocs, its ceiling was insulated with a thick layer of straw. A shaft ventilation system is installed in the cowshed. Cows’ bed places were covered with a straw. A tied cowshed is an old technology, and about half of cowsheds in Lithuania are still of this type. In the tied cowshed 200 cows were kept.

Two feeding tracks are installed and cows are tied on both sides of them. The cowshed was insulated, had a ceiling on which straw was stored. In the cold cubicle cowshed 220 cows were kept, its walls and roof were uninsulated, it was covered with tin sheets. The cows are kept in shallow cubicles whose floors are covered with rubber mats. A non-channel, ridge – slit ventilation system is installed. Air enters the shed through wall openings which are covered with netting and it leaves the shed through ridge openings. Air flow is controlled by moving the curtains and changing the size of wall openings. In the semi-insulated cubicle cowshed 230 cows are kept, the average heat transmission coefficient of shed walls is 3.3 W/(m² K) and of roof is 0.45 W/(m² K). Fresh air enters through wall openings controlled by curtains and polluted air is removed through controlled ridge openings. In the cowshed no-bedding technology is applied, recreation cubicles were covered with rubber mats, and manure tracks are covered with grids.

The investigation was performed during different seasons of the year and the variation of basic microclimate indexes (air temperature, relative humidity) in sheds and outdoors was estimated. The air temperature and relative humidity were recorded hourly using the measuring device COX TRACER Almemo 2590-9, made by Ahlborn GmbH, Germany. The measured temperatures ranged from –30 °C to +40 °C. The accuracy of the measured temperatures was ±0.3 °C and the accuracy of the measured air humidity was ±3%. 7 sensors were used, 2 of them were placed outdoors on the northern side of the shed, 5 sensors were placed in the different locations of the shed.

The obtained data was analysed by applying the multinomial correlation and regression method. The data reliability was based on Stjudents criterion. The difference line of standard error and lowest reliability was calculated according to the level of statistical significance p<0.05.

Results and discussion

During the analysis of air temperatures and relative humidity in the sheds, the effectiveness of ventilation systems was assessed. At different periods of the year the measurements lasted from 124 days (in the tied cowshed) to 165 days (in the cold cubicle cowshed). The identified microclimate indexes during measurements are given in Table 1. Detailed analysis of air temperatures and humidity was performed in all investigated sheds. The data of three differently insulated sheds are given in Fig.1–3.

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<td>0.9–29.0</td>
</tr>
</tbody>
</table>

During the investigation air temperatures outdoor fluctuated within the range from –21.2 °C to 32.1 °C. During the measurements average temperatures were within recommended limits in all sheds but in different sheds various temperature fluctuation patterns were observed. In the cold cowshed the temperatures fluctuated within big range from –4.2 °C to 33.5 °C, in the insulated sheds the fluctuation was smaller (maximal temperatures were lower only by a few degrees than in the cold cowshed and in the coldest periods the temperatures did not fall lower than 0 °C). It should be
emphasized that during heat periods temperatures were too high in all sheds, in the uninsulated cowshed they were higher by 10 °C than maximal recommended temperatures (24 °C), in the insulated cowsheds they were higher by 4–5 °C, too high temperatures were also measured in the pig shed. The variation of temperatures in sheds depends on shed design walls insulation, animal density and ventilation rate. The lowest temperature recorded in the cold cowshed was –14.2 °C, by 7 °C lower than recommended minimal temperature. At such temperature cows’ productivity decreased and fodder costs increased. But it continued for a short period with outdoor temperatures lower than –20 °C (Fig. 2). In other sheds it was warm at cold periods. In all sheds a very strong correlation between air temperatures in a shed and outdoor was estimated (R²>0.63), except the tied cowshed. It could have been caused by too low ventilation rate in the tied cowshed after closing ventilation channels.

The biggest problem in sheds is not unfavourable temperature but high air humidity. The highest humidity was in the insulated sheds. The relative air humidity varied from 33% to 98% (average 71.7%). During more than a half of measurement period the air in the shed was too humid i.e. more humid than maximally allowed rate. Having assessed temperatures the air humidity could not exceed 91%. The air relative humidity increases at night after closing the door. In summer the installed natural ventilation system is not effective enough, therefore, in warm periods windows and doors have to be opened. In the period of the whole investigation in the tied cowshed average relative humidity was 84.2%, it is not very high value but it is higher by 8.6% than the maximally allowed average air humidity. In this cowshed the air was more humid than recommended nearly through the whole period of investigation. (Fig.3). The air was dryer in less insulated sheds and in these sheds the average relative air humidity of the measurement period was lower than average maximal level (in the cold cubicle shed it was lower by 18.3%, in the semi-insulated cubicle shed – by 6.6%). In these sheds the humid air was observed only during short periods. During the whole period of investigation the air humidity was lower than maximum allowed level only in the pig shed. The air humidity in sheds mostly increased with the outdoor temperatures falling below 0 °C. The reason for this is too much closed ventilation channels in order to maintain higher temperatures in the shed.

After summarising the investigation results, the outdoor temperature intervals, which cause unfavourable microclimate in sheds, are given in Table 2. Most problems concerning unfavourable microclimate in all sheds is due to increases air humidity. Air humidity in sheds increases significantly when outdoor temperatures fall. It is possible to conclude that the less insulated the shed is and the lower temperature is in it, the dryer the air is in the shed. In the cold cubicle cowshed the humidity increases only when outdoor temperatures fall below –10 °C, and in the insulated tied shed – below –11 °C. Such results are conditioned by incorrect regulation of air supply channels and improperly maintained ventilation rate in the shed. The results of these measurements are confirmed by the investigations carried out by Kang and Lee (2008) and other scientists (Teye et al., 2008; Kaasik and Maasikmets, 2013; Zhao et al., 2007). Their results show that too low ventilation rate in a shed causes poor air quality indoors. It is not sufficient to install ventilation systems correctly, it is necessary to regulate them properly in respect of varied outdoor climate conditions.

The best way is to analyse dynamics of air parameters in a shed and according to the data to assess ventilation effectiveness. Of all mostly fluctuating air parameters (air temperatures, relative humidity), temperatures are the best index to assess ventilation. According to our investigation and the investigation performed by Pajumagi (2007), it is possible to ensure microclimate within optimal range in all sheds including the cold ones all year round provided that ventilation systems are properly installed and controlled. The temperatures in uninsulated sheds can be too low only during extremely cold periods. Under Lithuanian climate conditions such periods are short and they do not cause serious problems.
Table 2. Outdoor climate conditions which cause unfavourable microclimate in sheds (P<0.04)

<table>
<thead>
<tr>
<th>Shed</th>
<th>When were air temperatures too low in shed?</th>
<th>When were air temperatures too high in shed?</th>
<th>When was air relative humidity too high in shed?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calves shed</td>
<td>not observed</td>
<td>when ( t_i &gt; 26 , ^\circ\text{C} )</td>
<td>when ( t_i &lt; 14 , ^\circ\text{C}, \Delta t &gt; 7 , ^\circ\text{C} )</td>
</tr>
<tr>
<td>Meat pigs shed</td>
<td>not observed</td>
<td>when ( t_i &gt; 23 , ^\circ\text{C} )</td>
<td>when ( t_i &lt; 2 , ^\circ\text{C}, \Delta t &gt; 12 , ^\circ\text{C} )</td>
</tr>
<tr>
<td>Half-deep insulated cowshed</td>
<td>not observed</td>
<td>when ( t_i &gt; 27 , ^\circ\text{C} )</td>
<td>when ( t_i &lt; 6 , ^\circ\text{C}, \Delta t &gt; 13 , ^\circ\text{C} )</td>
</tr>
<tr>
<td>Insulated tied cowshed</td>
<td>not observed</td>
<td>not observed</td>
<td>when ( t_i &lt; 11 , ^\circ\text{C}, \Delta t &gt; 7 , ^\circ\text{C} )</td>
</tr>
<tr>
<td>Cold cubicle cowshed</td>
<td>when ( t_i &lt; 13 , ^\circ\text{C} )</td>
<td>when ( t_i &gt; 24 , ^\circ\text{C} )</td>
<td>when ( t_i &lt; 10 , ^\circ\text{C}, \Delta t &gt; 6 , ^\circ\text{C} )</td>
</tr>
<tr>
<td>Semi-insulated cubicle cowshed</td>
<td>not observed</td>
<td>when ( t_i &gt; 25 , ^\circ\text{C} )</td>
<td>when ( t_i &lt; 1 , ^\circ\text{C}, \Delta t &gt; 9 , ^\circ\text{C} )</td>
</tr>
</tbody>
</table>

\( t_o \) – air temperature outdoor \(^\circ\text{C}\); \( t_i \) – air temperature in shed \(^\circ\text{C} \); \( \Delta t \) – differences of air temperatures in shed and outdoor \((t_i-t_o)\), \(^\circ\text{C}\).

Complex and expensive equipment, which is necessary for the analysis of air quality parameters, is not required for controlling ventilation systems in sheds. According to our investigation results it is recommended to change ventilation rate in respect to temperature differences outdoors and in a shed. Good correlation between air relative humidity in a shed and temperature differences outdoor and in a shed was estimated. The correlation was good in the tied, cold cubicle cowshed and calf shed \((R^2>0.8)\), in other sheds it was weak \((R^2<0.6)\). After assessing kept animals and thermal characteristics of shed construction, in each shed it is possible to prepare optimal algorithm for controlling ventilation rate according to temperature variation in a shed and outdoors.
Conclusions

In insulated sheds (pig shed, tied half-deep cow shed, heifer/calf shed) temperatures are maintained within limits in winter and in heat periods temperatures are higher by a few degrees than the recommended level. The highest temperatures were in the cold cowshed (10 °C higher than recommended). For a short period in this cowshed the lowest temperature was –14.2 °C, by 7 °C lower than the recommended minimal level (with outdoor temperatures lower than –20 °C).

The main problem in all sheds is not unfavourable temperatures but high air humidity. In the insulated sheds it was too humid even in warm periods of the year. In the cold sheds air humidity increased with outdoor temperatures were below –10 °C, and in the insulated shed - with outdoor temperatures below –11 °C. From all measured sheds, the air humidity met the regulations best in the pig shed, cold cubicle cowshed and semi-insulated cubicle cowshed.

The main reason for unfavourable microclimate in sheds was not the improperly installed ventilation system but incorrect maintenance of ventilation systems and very frequently too low rate of ventilation.

After assessment of temperature variation in a shed and outdoors, it is recommended to prepare optimal algorithm for temperature control and to regulate ventilation rate according to it in each shed. In order avoid too high temperatures in sheds with natural ventilation system during warm periods, it is necessary to use additional instruments for increasing ventilation rate.

References


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Properties of Briquettes from Recovered Paper and Board

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Abstract

Worldwide increasing energy demand is today permanently covered by a majority of non-renewable energy sources, namely by coal, crude oil and natural gas. This causes the rapid decline of their reserves and the time gets near when they will be run out. Therefore in last years the exploitation of renewable energy sources is permanently preferred. One of alternative fuel forms is the fuel on the basis of paper waste. In this paper the results of tests are published, which were carried out using six sorts of recovered paper and board (group and grade 1.05, 1.07, 2.01, 2.05, 2.07 and 2.08 according to ČSN EN 643), pressed in form of briquettes. During the tests following briquettes parameters were watched: moisture content, ash amount, length and diameter, weight, density, rupture force and mechanical durability. It was proved that briquettes made from recovered paper and board are compared with briquettes from wood waste are of high density, high mechanical durability and for their rupture the relatively high force is necessary. But at the same time they have high ash amount and low combustion heat.

Key words: renewable energy sources, recovered paper and board, briquetting, properties of briquettes, mechanical durability

Introduction

Today the comfortable life is paid with the expressive consumption of energy in its all forms. The non-renewable energy sources reserves are limited and they exhaust. Nevertheless they supply about four fifths of energy consumption. But in last decades the renewable energy sources are preferred. One of alternative forms of fuel, made from renewable sources, is the fuel on the basis of paper waste. First of all it is recommended to recycle this raw material – to use it as a material (McKinney, 1995). But in several last years it is a paper waste surplus on the world market and therefore the interest of specialized firms in this raw material decreases. Besides not every paper waste is apt for recycling. E.g. chancery paper, exercise-book paper, magazine paper, newspaper, boxes, cartoons or boards are suitable. E.g. wet, greasy or otherwise polluted paper or coverings from paper and another material (e.g. besides paper coverings Tetra-pak contain aluminum or polyethylene foil, too) are not suitable. Energetic use becomes an interesting alternative and it is certainly more suitable than the paper waste disposal. Besides it is necessary to keep in mind that cellulose fibers progressively lose their original properties. Therefore the paper recycling can be repeated only 5 or 6 times. Then the raw material is unusable (Kupsa, 2009; Tymich, 2011; Tymich, Lešikar, 2011).

Paper is a flexible, sufficiently consistent mass, made mostly from vegetable substance and finished in form of thin sheets. Doubtless it is one of materials without which our everyday life is unimaginable. History of its production is old and at the same time interesting, too. Already more than 5000 years ago the parchment paper was produced in Egypt from medullas of cypress-grass (Cyperus Papyrus) stems. The production was relatively demanding and therefore the price was high. At the beginning of the 2nd century in China the paper production was significantly developed, as the rests of silk and hemp were used as the initial raw material. Later the cotton and flax waste was utilized. In the same way the hand-made paper is produced up to the present day. The modern industrial paper production is a relatively complicated process. In principle two steps concur – the paper pulp production and the paper production (internet source 1, 2012; internet source 2, 2012).

The fuel briquettes are mostly of circular section, eventually of square, rectangular or hexagonal section with rounded corners. The briquettes size depends above all on the used press type. Cylindrical briquettes are most often of 50 mm, 65 mm or 90 mm diameter, briquettes in form of blocks are usually of 100 x 150 mm section. The briquette length is proportional to the material quantity in the press chamber. The length of cylindrical briquettes is mostly often 0.5 to 1.5 of their diameter, of block form briquettes about 65 mm (Basore, 1929, Sheridan, Berte, 1929, Plistil et al 2004). Besides the shape of briquettes the combustible materials are processed in the shape of pellets [Plistil, 2005, Novakova, Brozek, 2008, Punko, Gavrilovich, 2009].

But the briquetting technology is not limited only to non-metallic materials [Brozek, 2001a, Brozek, 2011, Brozek, Novakova, 2011, Brozek et al, 2012, Brozek, 2013, Kupsa, 2009, Novakova, Brozek, 2009]. It is used also for processing of chips resulting from metallic materials machining be it on the ferrous basis (steel, cast iron) [Brozek, 2001b] or on the non-ferrous basis [Brozek, Novakova, 2010]. In this case the waste volume reduction, handling facilitation or possibility of its as following material utilization are the main aims.

The briquettes mechanical properties are very important. They influence expressly e.g. the storage ability. By author it was experimentally proved (Brozek, Novakova, 2011; Brozek, 2013) that at storage the briquettes mechanical properties decrease. The decrease depends above all on the storage conditions and storage time. The adequate mechanical properties level influences also the possible handling from their production, packing and sale to the incineration at the final user.

Material and Methods

In the Czech Republic the demands on the briquettes properties are prescribed by the Directive of Ministry of the Environment Nr. 14-2009. It requires the briquettes minimum density of 900 kg·m⁻³. The briquettes strength requirements are not prescribed. Nevertheless for operational reasons the adequate compactness is very important in
order that at a common handling neither crumbling nor disintegration occur. The briquettes minimum gross calorific value must be 17 MJ·kg\(^{-1}\), the total moisture content max. 10 per cent by weight and the ash content max 1.5%.

But the above mentioned Directive concerns to briquettes made from wood waste, alternatively to wood waste with maximum 20% of vegetable waste. Although it is a case of a different material, briquettes from paper waste are evaluated according to these technical requirements. In the Czech Republic the special technical requirements for briquettes from paper waste still do not exist.

The properties of briquettes made from six different sorts of recovered paper and board were watched (according to ČSN EN 643, 2002), namely old corrugated containers (group 1, grade 05), telephone books (group 1, grade 07), newspapers (group 2, grade 01), sorted office paper (group 2, grade 05), white woodfree books (group 2, grade 07) and coloured woodfree magazines (group 2, grade 08). Before briquetting all samples were shredded using shredder of cross cut 4 x 18 mm.

Ahead of briquetting the moisture content (according to ČSN EN 14774-2, 2010), ash amount (according to ČSN EN 14775, 2010) and gross calorific value (according to ČSN EN 14918, 2010) were determined.

Then the raw material was without other treatment briquetted using the briquetting press type “BrikStar 30-12” (Briklis, Malšice, Czech Republic) (internet source 3, 2012) of 50 mm pressure chamber diameter. From each material at least 50 pieces of briquettes were made, what made possible to carry out the measured values statistical evaluation.

The tests of briquettes mechanical properties were carried out according to the method used by author during several years for testing of briquettes made from different nonmetallic (Brožek, 2001a, Brožek, 2011, Brožek et al, 2012; Brožek, 2013) and metallic (Brožek, 2001b, Brožek, Nováková, 2010) materials. The method of operation is relatively simple. Using the slide caliper the diameter and length of each briquette are measured. By weighing their weight is determined. Then the briquettes are placed between the plates of the universal tensile testing machine and continuously loaded till to the briquette rupture. The method of operation is presented in Fig. 1. The test is finished at the briquette rupture, which is accompanied with the rapid load decrease. From the load indicator the maximum load is noted down.

By the above mentioned method obtained values are mathematically evaluated. From diameter and length volume, next from volume and weight density and from length and force for rupture needed for destruction per unit of length are calculated. Using the unit of length the influence of briquettes different length is eliminated.

The determination of the mechanical durability of briquettes (according to CSN EN 14961-1, 2010 and CSN EN 15210-2, 2011) was the part of carried out tests.

Results and Discussion

Results of carried out tests are presented in following table and figures. Tab. 1 presents the properties of tested papers ahead of briquetting (moisture content, ash amount and gross calorific value). Fig. 2 presents results of length measurements, Fig. 3 presents results of diameter measurements, Fig. 4 presents results of weight measurements, Fig. 5 contains results of calculated briquettes density and Fig. 6 presents results of rupture force measurements. In all these figures the standard deviation is demonstrated by the line segments.

<table>
<thead>
<tr>
<th>Sample designation</th>
<th>Moisture content %</th>
<th>Ash amount %</th>
<th>Gross calorific value MJ·kg(^{-1})</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.05</td>
<td>5.5</td>
<td>13.9</td>
<td>15.5</td>
</tr>
<tr>
<td>1.07</td>
<td>6.1</td>
<td>2.9</td>
<td>16.2</td>
</tr>
<tr>
<td>2.01</td>
<td>4.6</td>
<td>30.1</td>
<td>11.7</td>
</tr>
<tr>
<td>2.05</td>
<td>4.3</td>
<td>22.8</td>
<td>14.5</td>
</tr>
<tr>
<td>2.07</td>
<td>4.6</td>
<td>21.6</td>
<td>18.0</td>
</tr>
<tr>
<td>2.08</td>
<td>5.3</td>
<td>11.0</td>
<td>18.0</td>
</tr>
</tbody>
</table>

From the results presented in Tab. 1 it follows that the moisture content at all tested materials ranged in the relatively low level, from 4.3% (sample 2.05) to 6.1% (sample 1.07).

From the point of view of the ash amount (Tab. 1) between six tested materials the significant differences exist. The lowest ash amount was determined at the sample 1.07 (2.9%). At the next two samples (2.08 and 1.05) the ash amount was higher than 10%, at the next two samples (2.07 and 2.05) the ash amount was higher than 20%. The highest ash amount (30.1%) was determined at the sample 2.01.

The gross calorific values (Tab. 1) ranged from 11.7 (sample 2.01) to 18.0 (samples 2.07 and 2.08) MJ·kg\(^{-1}\). From this point of view only the samples 2.07 and 2.08 met the requirements.
From the results published in Fig. 2 it is evident that the average length of briquettes made from all six sorts of paper waste is in the relatively wide range from 34.9 mm (sample 2.05) to 51.0 mm (sample 1.05).

From results published in Fig. 3 it is evident that briquettes made from all six tested materials enlarged their diameter compared to the diameter of the pressure chamber diameter (50 mm). The enlargement was relatively small and for all tested materials it ranged from 0.8 mm (samples 2.05 and 1.05) to 1.3 mm (sample 1.07).
From results published in Fig. 4 it is evident that the briquettes weight ranged relatively widely from 74.0 g (sample 1.07) to 116.6 g (sample 1.05).

From results published in Fig. 5 it is evident that the briquettes density ranges relatively widely from 1009 kg·m$^{-3}$ (sample 1.07) to 1151 kg·m$^{-3}$ (sample 2.07).

From the results published in Fig. 6 it is evident that the rupture force of the briquettes made from paper ranges relatively widely from 84 N·mm$^{-1}$ (sample 1.06) to 198 N·mm$^{-1}$ (sample 3.05). From this point of view briquettes were not similar.

From results published in Fig. 7 it is evident that the mechanical durability of the briquettes ranged relatively widely from 97% (sample 1.05) to 100% (sample 2.07).
As it follows from Fig. 7 the mechanical durability of all briquettes is very high. The value just below 99% was determined at the sample 2.08; the values over 99% were found at all next samples.

Figure 8. Test results – relationship between rupture force and density

The graphical representation of the briquettes rupture force and density is shown in Fig. 8. It is evident that the highest density was determined at briquettes made from sample 2.07 (white woodfree books). The highest rupture force was determined at the briquettes made from the paper 2.05 (sorted office paper).

From Fig. 8 it follows also that the properties of the briquettes made from five materials (1.05, 2.01, 2.05, 2.07 and 2.08) were relatively similar. The briquettes made from telephone books (1.07) were a bit deviating. Despite this fact it is possible to state that also these briquettes accommodated the requirements on the mechanical properties.

The comparison of obtained results with other works is in this case difficult. The author actually knows only one published work (Novakova, Brozek, 2011) studying properties of briquettes made from paper waste. For briquetting the cuttings of two different sorts of newspaper were used (dimensions: width about 3 to 10 mm, average length about 300 mm), and common shredded chancery paper, made using two types of shredders (longitudinal cut 3 x 300 mm and cross cut 3 x 30 mm). For briquetting the press type “BrikStar 50” (Briklis, Malsice, Czech Republic) of the pressure chamber diameter 65 mm was used. From the published results it follows that briquettes made from shredded chancery paper are of higher mechanical properties (density about 1045 kg·m⁻³, rupture force at the use of longitudinal cut about 126 N·mm⁻¹, at the use of cross-cut 172 N·mm⁻¹) than briquettes made from newspaper shavings (density about 790 kg·mm⁻³, rupture force about 45 N.mm⁻¹). By the results comparison we find that at the use of briquetting press of smaller pressure chamber diameter the briquettes density and rupture force increase considerably.

Other works, studying the briquettes and pellets properties, exist, too. But they engage in other materials than paper waste, primarily in briquettes made from wood waste (Basore 1929; Brozek et al.: 2012; Brozek, 2013; Sheridan, Berte, 1959), from energy plants (Kakitis et al., 2010; Plistil et al., 2004; Plistil et al., 2005), or from alternative fuels (Kolarova, 2011). Their authors concentrate primarily on energy properties, but not on mechanical properties. Therefore the comparison of their results gained at the use of briquettes from paper waste is not possible owing to tested materials dissimilarity.

Conclusion

In the paper the results of briquettes mechanical properties are published. Briquettes were made from six sorts of recovered paper and board (according to ČSN EN 643, 2002), namely old corrugated containers (group 1, grade 05), telephone books (group 1, grade 07), newspapers (group 2, grade 01), sorted office paper (group 2, grade 05), white woodfree books (group 2, grade 07) and coloured woodfree magazines (group 2, grade 08). Before briquetting all samples were shredded using shredder of cross cut 4 x 18 mm. These materials were pressed without any admixtures.

Ahead of briquetting the paper properties (moisture content, ash amount and gross calorific value) were determined. For briquetting the briquetting press type “BrikStar 30-12” of the pressure chamber diameter 50 mm was used. Briquettes were judged from several standpoints – length, diameter, weight, density, mechanical durability and rupture force using plate-loading test.

After evaluation of all measured values it is possible to say that all briquettes made from six sorts of recovered paper and board are from the user’s view suitable. Briquettes technical parameters were objectively determined using above mentioned tests, adopted from methods for testing of briquettes made from wood waste. Compared with briquettes from wood waste briquettes from paper waste are of considerably higher density, mechanical durability and rupture force. But combustion heat of all sorts of paper waste is lower than combustion heat of wood waste and contemporarily ash amount is many times higher.
References


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Electromagnetic Investigation of Multi-Phase Windings of Alternating Current Machines

Jonas Bukšnaitis, Tadas Kulikauskas
Aleksandras Stulginskis University, Lithuania

Abstract

The research electromagnetic efficiency of a concentrated six-phase winding has been accomplished. The phase change sequence of six-phase winding was determined at first, and the electric circuit layout of the analyzed winding was created on the base of theory of three-phase windings. Instantaneous space functions of rotating magnetomotive force were created using developed layout and instantaneous values of phase currents at time moments \( t = 0 \) and \( t = T / 12 \) with aim to determine the harmonic spectrum of rotating magnetomotive force induced by six-phase winding. Harmonic analysis of these functions was accomplished and the electromagnetic efficiency factor of the considered six-phase winding was calculated on the basis of obtained results. Calculated factor was compared with electromagnetic efficiency factor of concentrated three-phase winding, and it was determined that it was 20.0% higher compared to the latter. Additionally, it was determined that the amplitude value of rotating magnetomotive force fundamental harmonic of analyzed six-phase winding was 1.983 higher than the same amplitude value of analogous three-phase winding. This means that the energy factors of alternating current electrical motor designed and manufactured using concentrated six-phase winding would be considerably higher compared to motor with concentrated three-phase winding.

Introduction

During the last decade a lot of scientific investigations of alternating current six-phase machines were accomplished. In the paper [1] the stability study of a multi-phase (six-phase) induction machine has been performed by applying the eigenvalues stability criterion to the small displacement equations obtained by linearization about an operating point. The effect of common mutual leakage reactance, which depends upon the winding pitch and the operating point. The research electromagnetic efficiency of a concentrated six-phase winding has been accomplished. The phase change sequence of six-phase winding was determined at first, and the electric circuit layout of the analyzed winding was created on the base of theory of three-phase windings. Instantaneous space functions of rotating magnetomotive force were created using developed layout and instantaneous values of phase currents at time moments \( t = 0 \) and \( t = T / 12 \) with aim to determine the harmonic spectrum of rotating magnetomotive force induced by six-phase winding. Harmonic analysis of these functions was accomplished and the electromagnetic efficiency factor of the considered six-phase winding was calculated on the basis of obtained results. Calculated factor was compared with electromagnetic efficiency factor of concentrated three-phase winding, and it was determined that it was 20.0% higher compared to the latter. Additionally, it was determined that the amplitude value of rotating magnetomotive force fundamental harmonic of analyzed six-phase winding was 1.983 higher than the same amplitude value of analogous three-phase winding. This means that the energy factors of alternating current electrical motor designed and manufactured using concentrated six-phase winding would be considerably higher compared to motor with concentrated three-phase winding.

Peculiarities of connecting six-phase winding to a power supply

Assume that the positive sequence symmetric voltage system of six-phase power supply source is the following:

\[
\begin{align*}
    u_A &= U_{A_m} \sin \omega t; \\
    u_B &= U_{B_m} \sin(\omega t - 2\pi / 6); \\
    u_C &= U_{C_m} \sin(\omega t - 4\pi / 6); \\
    u_D &= U_{D_m} \sin(\omega t - 6\pi / 6); \\
    u_E &= U_{E_m} \sin(\omega t - 8\pi / 6); \\
    u_F &= U_{F_m} \sin(\omega t - 10\pi / 6).
\end{align*}
\]  

Phase windings of six-phase winding are typically marked in such order: U, X, V, Y, W, Z. Space angles of \( 2\pi / 6 \) electrical radians between beginnings or ends of adjacent phase windings are formed. The least distorted rotating...
magnetic field induced by six-phase winding will move in positive direction, when phase windings will be connected to supply voltage phases using one of ways indicated in Table 1.

The least distorted rotating magnetic field induced by a six-phase winding will move in a negative direction, when phase windings will be connected to supply voltage phases using one of ways indicated in Table 2.

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Voltage phases</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A B C D E F</td>
</tr>
<tr>
<td>2</td>
<td>F A B C D E</td>
</tr>
<tr>
<td>3</td>
<td>E F A B C D</td>
</tr>
<tr>
<td>4</td>
<td>D E F A B C</td>
</tr>
<tr>
<td>5</td>
<td>C D E F A B</td>
</tr>
<tr>
<td>6</td>
<td>B C D E F A</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Voltage phases</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A F D C B E</td>
</tr>
<tr>
<td>2</td>
<td>F E D C B A</td>
</tr>
<tr>
<td>3</td>
<td>E D C B A F</td>
</tr>
<tr>
<td>4</td>
<td>D C B A F E</td>
</tr>
<tr>
<td>5</td>
<td>C B A F E D</td>
</tr>
<tr>
<td>6</td>
<td>B A F E D C</td>
</tr>
</tbody>
</table>

It could be assumed that if any two voltage phases indicated in variants of Table 1 or 2 are switched with each other when connecting them to six-phase winding, rotating magnetic field distortions would increase significantly, and the electromagnetic efficiency factor would be decreased noticeably.

**Research object**

The concentrated six-phase winding of the following parameters was used in the research: number of pole and phase slots \( q = 1 \), number of rotating magnetic field poles \( 2p = 2 \), number of stator magnetic circuit slots \( Z = 2 \cdot 6 \cdot 1 = 12 \), pole pitch measured in slots \( \tau = Z / (2p) = 12 / 2 = 6 \), stator magnetic circuit slot pitch measured in electrical degrees \( \alpha = 360° / Z = 360° \cdot 1 / 12 = 30° \).

Alternation of six-phase winding phases belongs to the positive sequence, since the fundamental rotating magnetic field harmonic induced by these windings is the first space harmonic which belongs to this sequence. Then spatial distribution of phase winding beginnings and ends of analyzed winding must be as denoted here: U1; W2; X1; Z2; V1; U2; Y1; X2; W1; V2; Z1; Y2. Such arrangement is supported by Fig. 1. Given phase change sequence corresponds to one pair of poles of induced rotating magnetic field.

**Figure 1. Positive sequence phase change of a six-phase winding**

The distribution of discussed concentrated winding active coil sides into magnetic circuit slots is provided in Table 3.

<table>
<thead>
<tr>
<th>Phase change</th>
<th>U1</th>
<th>W2</th>
<th>X1</th>
<th>Z2</th>
<th>V1</th>
<th>U2</th>
<th>Y1</th>
<th>X2</th>
<th>W1</th>
<th>V2</th>
<th>Z1</th>
<th>Y2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of coils in a group</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Slot No.</td>
<td>Z</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>10</td>
<td>11</td>
</tr>
</tbody>
</table>

On the basis of Table 3, the distribution separate phase coils of the discussed concentrated six-phase winding into slots of magnetic circuit is given in Table 4.
Table 4. The distribution of separate phase coils of the discussed winding into slots of magnetic circuit

<table>
<thead>
<tr>
<th>U phase</th>
<th>X phase</th>
<th>V phase</th>
<th>Y phase</th>
<th>W phase</th>
<th>Z phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>→1 – 6→</td>
<td>→3 – 8→</td>
<td>→5 – 10→</td>
<td>→7 – 12→</td>
<td>→9 – 2→</td>
<td>→11 – 4→</td>
</tr>
</tbody>
</table>

It is apparent from Table 4, that winding span of concentrated six-phase winding \( y \), differently from concentrated three-phase winding \( (y = \tau) \), was reduced by \( \tau/6 \) and became equal to five slot pitches \( (\tau = 6; \ y = 5) \). As it is known, such a possible reduction of winding span greatly decreases amplitudes of rotating magnetic fields generated by the fifth and seventh harmonics. Amplitude of rotating magnetic field induced by the first (fundamental) harmonic is lessened not much due to such decreased winding span. Consequently the discussed winding should be significantly more efficient from electromagnetic perspective, compared to concentrated three-phase winding.

According to data from Tables 3 and 4 the electric circuit layout of the concentrated six-phase winding is created (Fig. 2, (a)).

![Electric circuit layout of the concentrated six-phase winding](image)

**Figure 2.** The electric circuit layout of the concentrated six-phase winding (a) and spatial distributions of rotating magnetomotive forces of this winding at time moments \( t = 0 \) (b) and \( t = T/12 \) (c)

**Results of research**

Suppose that electric current amplitude magnitudes in concentrated six-phase winding are as follows:

\[
I_{U, \text{m}}^* = I_{X, \text{m}}^* = \ldots = I_{Z, \text{m}}^* = 1.
\] (2)

After connecting phase supply voltages to the star-connected phase windings according to the first variant of Table 1, the instantaneous values of currents at time moment \( t = 0 \) would be as expressed:

\[
i_{U}^* = I_{mU}^* \sin \omega t = 0;
\] (3)

\[
i_{X}^* = I_{mX}^* \sin \left( \omega t - \frac{2\pi}{6} \right) = I_{mX}^* \sin(-60^\circ) = -0.866;
\] (4)

\[
i_{Y}^* = I_{mY}^* \sin \left( \omega t - \frac{4\pi}{6} \right) = I_{mY}^* \sin(-120^\circ) = -0.866;
\] (5)

\[
i_{V}^* = I_{mY}^* \sin \left( \omega t - \frac{6\pi}{6} \right) = I_{mY}^* \sin(-180^\circ) = 0;
\] (6)
The conditional changes of magnetomotive force in the slots of active coil sides; $i^*_w$.

For considered concentrated six-phase winding with $q = 1$, the relative magnitude of effective conductors in a single magnetic circuit slot is $N^*_g = 1$.

The expression of conditional change of concentrated winding magnetomotive force is the following:

$$F^*_g = i^*_i, N^*_i;$$

where $F^*_g$ – the conditional changes of magnetomotive force in the slots of active coil sides; $i^*_i$ – the relative magnitudes of instantaneous values of currents flowing through respective phase windings.

According to formulas (3÷8) and (9), and also based on Fig. 2, (a), the conditional changes of magnetomotive force in the slots of magnetic circuit are determined (Table 5).

### Table 5. Conditional magnetomotive force variations in magnetic circuit slots at time moments $t = 0$ and $t = T/12$

<table>
<thead>
<tr>
<th>Slot No.</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conditional changes of magnetomotive force in slots</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>at $t = 0$</td>
<td>0</td>
<td>–0.866</td>
<td>–0.866</td>
<td>–0.866</td>
<td>–0.866</td>
<td>0</td>
<td>0</td>
<td>0.866</td>
<td>0.866</td>
<td>0.866</td>
<td>0.866</td>
<td>0</td>
</tr>
<tr>
<td>at $t = T/12$</td>
<td>0.5</td>
<td>–0.5</td>
<td>–0.5</td>
<td>–1.0</td>
<td>–1.0</td>
<td>–0.5</td>
<td>–0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>1.0</td>
<td>1.0</td>
<td>0.5</td>
</tr>
</tbody>
</table>

On the base of results presented in Table 5 the spatial distributions of instantaneous rotating magnetomotive force at pre-defined time moments ($t = 0$ and $t = T/12$) are created (Fig. 2, (b), (c)). Acquired results allow to state that the six-phase symmetric current system in concentrated six-phase winding will create the stair-shaped curves of magnetomotive force which move in space and periodically vary in time. Such stair-shaped functions of rotating magnetomotive force will have only odd harmonics, since they will be symmetric to coordinate axes at any moment of time. After applying the principle of superposition, such amplitudes of odd harmonics of instantaneous rotating magnetomotive force can be calculated using the following equation [5]:

$$F_{sv} = \frac{4}{\pi} F_{is} \sin \nu \frac{\beta_i}{2} + \frac{4}{\pi} F_{2is} \sin \nu \frac{\beta_2}{2} + \ldots + \frac{4}{\pi} F_{kis} \sin \nu \frac{\beta_k}{2} = \frac{4}{\pi} \nu \sum_{i=1}^{k} F_{is} \sin \nu \frac{\beta_i}{2};$$

where $F_{is}$ – conditional height of the $i$-th rectangle of the stair-shaped curve of instantaneous rotating magneto-motive force; $\beta_i$ – width of the $i$-th rectangle, expressed in electrical degrees of the fundamental space harmonic; $k$ – the number of rectangles which constitute the stair-shaped curve of instantaneous rotating magnetomotive force; $\nu$ – series number of odd space harmonic.

With reference to data in Table 5 and Fig. 1, (b), the parameters of negative half-period of instantaneous rotating magnetomotive force of analyzed winding are the following: $k = 2; F_{i1} = -0.866; F_{i2} = -0.866; \beta_1 = 150; \beta_2 = 90$°.

With reference to data in Table 5 and Fig. 1, (c), the parameters of negative half-period of instantaneous rotating magnetomotive force of analyzed winding are the following: $k = 3; F_{i1} = -1.0; F_{i2} = -0.5; F_{i3} = -0.5; \beta_1 = 150; \beta_2 = 90; \beta_3 = 30$°.

The conditional $F_{is}$ and relative $f_r$ magnitudes of magnetomotive force space harmonics created by six-phase winding were calculated according to expression (10), using presented parameters of rotating magnetomotive force functions. The identical results were obtained after expanding the space functions of rotating magnetomotive force at both moments of time (Table 6).

### Table 6. The results of harmonic analysis of rotating magnetomotive force space function of concentrated six-phase winding and the relative magnitudes of its space harmonics

<table>
<thead>
<tr>
<th>Series number of harmonic</th>
<th>1</th>
<th>5</th>
<th>7</th>
<th>11</th>
<th>13</th>
<th>17</th>
<th>19</th>
<th>23</th>
<th>25</th>
<th>29</th>
<th>31</th>
<th>35</th>
</tr>
</thead>
<tbody>
<tr>
<td>$F_{sv}$</td>
<td>–1.845</td>
<td>–0.099</td>
<td>–0.071</td>
<td>–0.168</td>
<td>0.142</td>
<td>0.029</td>
<td>0.026</td>
<td>0.080</td>
<td>–0.074</td>
<td>–0.017</td>
<td>–0.016</td>
<td>–0.053</td>
</tr>
<tr>
<td>$f_r = F_{sv}/F_{s1}$</td>
<td>1</td>
<td>0.054</td>
<td>0.038</td>
<td>0.091</td>
<td>0.077</td>
<td>0.016</td>
<td>0.014</td>
<td>0.043</td>
<td>0.040</td>
<td>0.009</td>
<td>0.009</td>
<td>0.029</td>
</tr>
</tbody>
</table>

It was obtained that the amplitude of the fifth rotating magnetomotive force harmonic for analyzed winding amounts to 5.4% in respect of the first harmonic, and 3.8% – compared to the seventh harmonic. Meanwhile, the
amplitude of the fifth rotating magnetomotive force harmonic for concentrated three-phase winding amounts to 20% in respect of the first harmonic, and 14.2% compared to the seventh harmonic [5].

From electromagnetic point of view, six-phase windings could be evaluated in a similar manner as their three-phase counterparts, using the electromagnetic efficiency factor, which can be expressed as [5]:

$$k_{ef} = 1 - \frac{\sum_{\nu=1}^{\infty} f_{\nu}^2}{1}$$

(11)

where $f_{\nu}$ – the relative magnitude of rotating magnetomotive force $\nu$-th harmonic.

On the basis of $f_{\nu}$ calculation results from Table 6, the electromagnetic efficiency factor of concentrated six-phase winding estimated using expression (11) was $k_{ef} = 0.844$. This estimated coefficient was compared with the electromagnetic efficiency factor of the analogical concentrated three-phase winding. Electromagnetic efficiency factor of the concentrated three-phase winding was $k_{ef} = 0.703$ [5]. It was ascertained that the electromagnetic efficiency factor of the concentrated six-phase winding is 20.0% higher in comparison to the same factor of the concentrated three-phase winding.

After opportunity to reduce the concentrated six-phase winding span by 1/6 of the pole pitch emerged, the fifth and seventh harmonics of magnetomotive force significantly decreased; instantaneous spatial functions of rotating magnetomotive force became noticeably closer to sinusoids, and consequently its electromagnetic efficiency factor increased strongly. It means that this winding could be used in a small-power six-phase alternating current machines.

Conclusions

The concentrated six-phase winding can be created by reducing its span by 1/6 of the pole pitch, which is not possible to accomplish in case of the concentrated three-phase winding. The winding span of the latter winding is equal to pole pitch.

The rotating magnetomotive force induced by the concentrated six-phase winding becomes noticeably closer to sine distribution due to increased number of steps in its spatial distribution, compared to the rotating magnetomotive force of the concentrated three-phase winding.

The amplitude of the fifth rotating magnetomotive force harmonic for analyzed winding amounts to 5.4% in respect of the first harmonic, and 3.8% – compared to the seventh harmonic.

The amplitude of the fifth rotating magnetomotive force harmonic for concentrated three-phase winding amounts to 20% in respect of the first harmonic, and 14.2% compared to the seventh harmonic.

The electromagnetic efficiency factor of the concentrated six-phase winding ($k_{ef} = 0.844$) is 20.0% higher than the same factor of the concentrated three-phase winding ($k_{ef} = 0.703$).

The amplitude value of rotating magnetomotive force fundamental harmonic of the concentrated six-phase winding ($F_{m1} = 1.845$) is 1.983 times higher than the amplitude value of rotating magnetomotive force of the three-phase winding ($F_{m1} = 0.955$).

Under significantly higher electromagnetic efficiency factor of the concentrated six-phase winding, this winding could be effectively used in a small-power six-phase alternating current machines.

References


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Infrasonic and Low Frequency Environment in the Shadow Zones of Noise Barriers

Ričardas Butkus, Gediminas Vasiliauskas
Aleksandras Stulginskis University, Lithuania

Abstract

Constant increase of life quality expands the number of activities that are necessary to satisfy the requirements of society. Increasing number of new technologies, machinery or equipment used in daily life together with positive outcomes generates secondary, unwanted consequences. Low frequency noise (LFN) is one of the most common environmental issues in urban areas and can be generated by the sources of both natural and artificial nature. Low frequency noise from artificial sources such as road and railway transport, airplanes as well as wind turbines, compressors or air conditioning stations is constantly growing. Transport noise is attributed as a source of low frequency noise yet the highest sound pressure levels usually lies in the frequency range from roughly 16 Hz to 5 kHz with dominant low frequencies in the range from 16 to 500 Hz. This frequency range is of common interest yet it has crucial role on annoyance, moreover the number of inhabitants under the sway of LFN and infrasound near highways is constantly increasing. The reduction of transport noise is usually implemented by installing noise barriers which lack infrasonic and low frequency attenuation and can even potentially amplify the subjective reaction to the transport noise because of inappropriate balance of low, mid and high frequencies. The aim of this research was to investigate the levels of low frequency noise and infrasound in the shadow zones of noise barriers.

Assessment of broadband noise is usually based on A-weighted time averaged sound pressure level or its modifications such as statistical level distribution levels \( L_{10}, L_{50} \) and similar. These methods correlate well with the loudness and annoyance of higher frequencies (for example traffic noise index TNI) but fail to objectively evaluate LFN. When prominent LFN components are present in frequency spectra A-weighted measurements should not be used. One of the simplest and easily implemented methods for the identification of low frequency problem is the \( \text{dB}(C) – \text{dB}(A) \) difference. This method was proposed by Blazier (Blazier 1981) for the evaluation of HVAC noise in dwellings. If the difference \( \text{dB}(C) – \text{dB}(A) \) is greater than 20 dB it indicates that there is a low frequency problem. Leventhall (Leventhall 2004) later reviewed this method and concluded, that it should not be used as annoyance predictor especially when infrasonic frequencies are analyzed. Scientifically, the use of A and C weightings justifies only the effects created via auditory system and does not take into account biological effects created by infrasound.
(Pereira and N. A. A., 2007). However, according to the recommendations of WHO, if the difference $\text{dB}(C) – \text{dB}(A)$ is >10 dB it is recommended to perform additional spectral analysis (Berglund, Lindvall et al., 1999).

There have been attempts in various countries to determine the significance of LFN on humans. Sound spectra values were selected as main criteria, describing LFN effects. Maximum levels of LFN were validated in most European countries and these levels are shown in Table 1.

**Table 1. Legislation requirements for low frequency noise from different countries**

<table>
<thead>
<tr>
<th>Frequency, Hz</th>
<th>Poland</th>
<th>Germany</th>
<th>Netherlands</th>
<th>Denmark</th>
<th>Sweden</th>
<th>Lithuania</th>
<th>ISO 226 threshold</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>103</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>80.4</td>
<td>95</td>
<td></td>
<td>90.4</td>
<td></td>
<td>103</td>
<td>95</td>
</tr>
<tr>
<td>12.5</td>
<td>83.4</td>
<td>87</td>
<td></td>
<td>93.4</td>
<td></td>
<td>87</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>66.7</td>
<td>79</td>
<td></td>
<td>76.7</td>
<td></td>
<td>79</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>60.5</td>
<td>71</td>
<td>74</td>
<td>70.5</td>
<td></td>
<td>71</td>
<td>74.3</td>
</tr>
<tr>
<td>25</td>
<td>54.7</td>
<td>63</td>
<td>64</td>
<td>64.7</td>
<td></td>
<td>63</td>
<td>65.0</td>
</tr>
<tr>
<td>31.5</td>
<td>49.3</td>
<td>55.5</td>
<td>55</td>
<td>59.4</td>
<td>56</td>
<td>56</td>
<td>56.3</td>
</tr>
<tr>
<td>40</td>
<td>44.6</td>
<td>48</td>
<td>46</td>
<td>54.6</td>
<td>49</td>
<td>48</td>
<td>48.4</td>
</tr>
<tr>
<td>50</td>
<td>40.2</td>
<td>40.5</td>
<td>39</td>
<td>50.2</td>
<td>43</td>
<td>41</td>
<td>41.7</td>
</tr>
<tr>
<td>63</td>
<td>36.2</td>
<td>33.5</td>
<td>33</td>
<td>46.2</td>
<td>41.5</td>
<td>34</td>
<td>35.5</td>
</tr>
<tr>
<td>60</td>
<td>32.5</td>
<td>28</td>
<td>27</td>
<td>42.5</td>
<td>40</td>
<td>28</td>
<td>29.8</td>
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<tr>
<td>100</td>
<td>29.1</td>
<td>23.5</td>
<td>22</td>
<td>39.1</td>
<td>36</td>
<td>24</td>
<td>25.1</td>
</tr>
<tr>
<td>125</td>
<td>26.1</td>
<td></td>
<td></td>
<td>36.1</td>
<td>36</td>
<td>21</td>
<td>20.7</td>
</tr>
<tr>
<td>160</td>
<td>23.4</td>
<td></td>
<td></td>
<td>33.4</td>
<td>34</td>
<td>17</td>
<td>16.8</td>
</tr>
<tr>
<td>200</td>
<td>20.9</td>
<td></td>
<td></td>
<td>32</td>
<td>14</td>
<td>13.8</td>
<td></td>
</tr>
<tr>
<td>250</td>
<td>18.6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>11.2</td>
</tr>
</tbody>
</table>

Data from different countries show the maximum permissible levels for both low frequencies and infrasound. It should be noted, that these levels are below hearing threshold (Leventhall, Benton et al., 2003) which shows the effect of LFN at inaudible levels. Annoyance of LFN was investigated by Moller (Moller, 1987; Moller and Pedersen, 2004). It was concluded that even negligible increase in level acts crucial role on annoyance at very low infrasonic frequencies as well as different hearing thresholds were reported at various studies. As reviewed by Leventhall (Leventhall, 2004), the annoyance of low frequencies should not be correlated with the results of physical measurements. The overall annoyance consists of more than just energy perceived but also includes attitude to noise source and other subjective factors (Guski, Felscher-Suhr et al., 1999). Various studies were carried out in order to determine the effects of these factors but unfortunately there is no unanimous agreement between the findings. There are very few studies on LFN and infrasound effects on living areas from transportation sources especially in agglomerations where noise barriers are used. The purpose of our study was to investigate the environment of infrasonic and low frequency noise in the shadow zones of noise barriers and adjacent agglomerations.

**Methodology**

The effectiveness of noise barrier depends on its height ($h$), absorption properties ($\alpha$), and length ($l$) as well as on distance from noise source ($a$). The matter of barrier’s dimensions and its distance from source and receiver is usually characterized as path length difference $\delta = (c+d) – (a+b)$ and is described by Fresnel’s number which is a function of frequency (principle scheme in Figure 1). It was reviewed by Neto and Rosao (2005) that the reduction of 10 dB for the central octave band of 63 Hz can be reached if $\delta$ value is approximately 4 meters and decreases twice as frequency doubles. As wavelength of infrasonic and low frequencies is relatively large, the sound wave diffraction as well as absorption is insignificant, i.e. the effect of noise barrier at low frequencies is negligible.

![Figure 1. Principle scheme of acoustic barrier](image)

Better attenuation of high frequencies of noise barrier can cause annoyance increase of low frequency noise. Assessment of the noise in the shadow zones of the lightweight noise barriers was done by calculating the difference $\text{dB}(C) – \text{dB}(A)$. Underestimation of noise using this method can be in near distances from barrier, yet the level of high frequencies tend to decrease notably while the attenuation of low frequencies is negligible. Areas behind noise barriers
and motorways with a large amount of heavy vehicle traffic should show high dB(C) – dB(A) levels. This may indicate that these agglomerations are exposed to noise with strong low frequency content.

The assessment of LFN environment in the shadow zones of noise barriers was performed by applying G-weighting correction to low frequency spectra. Determination of the G-weighted sound pressure levels was implemented by band analysis of the signal using the one third octave bandwidth sound pressure levels. Correction values of G-weighting were standardized by the standard ISO 7196:1995 which states that sound pressure levels below 90 dB(G) will “not normally be significant for human perception”. The assessment in our study was done with slightly lower level of 85 dB(G) which is evidently discussed in another papers and it typically covers lowest assessment criteria applied to very low frequency noise (Leventhall, Benton et al., 2003).

\[
L_p = 10 \cdot \lg \left[ \sum_{i=1}^{n} 10^{0.1 \left( L_{p,i} + \Delta L_{p,G} \right)} \right],
\]

where: \( L_{p,i} \) – sound pressure level in i’th octave band, dB; \( \Delta L_{p,G} \) – frequency correction, dB.

The decrease in sound energy represented as sound pressure level was performed by simultaneous measurements of noise. Two frequency analyzers were used to measure noise level on the source and receiver side at the same time. This method enabled to evaluate traffic noise and gave reliable results of noise reduction yet the traffic flow characteristics were the same at both measurement positions.

Measurements were undertaken using a class 1 Brüel&Kjær sound level meters (type 2250 and 2270). These level meters were equipped with the measuring microphones type 4189. The capability to extend the low frequency range to 6.3 Hz enabled to accurately measure third-octave band levels down to 6.3 Hz. Levels of lower infrasonic frequencies were not measured. As the G-weighted sound pressure levels were calculated in the frequency range of 6.3–200 Hz which means that the actual G-weighted noise levels in the environment might been slightly lower. This difference in level is likely to be relatively small as the G-weighting correction values at frequencies below 6.3 Hz are more than 20 dB if compared to peak sensitivity at 20 Hz.

Results

The decrease in acoustic energy doubling the distance from linear noise source can be calculated by using the mathematical dependence \( 10 \cdot \lg (r) \). For the case when the sound field is diffuse, i.e. there is a noise barrier between the source and receiver the prognostication of LFN attenuation is a complicated task. Accurate results of noise reduction can be obtained by physically measuring noise level at both sides of noise barrier. As distance from noise barrier increase, the C-weighted and A-weighted sound pressure level difference also tends to increase because of better absorption and shadowing effect of the noise barrier. This shows that acoustic environment at further distances (\( r > a \)) is less favorable because of dominant low frequency components in the sound spectra. The results of dB(C) – dB(A) difference shown in figure 2 exceed safe 10 dB WHO guideline at far distances.

![Figure 2. Calculated dB(C) – dB(A) difference at various distances from source](image)

As sound spectra depends mostly on the structure of traffic flow our results shown in figure 2 does not take into account the number of vehicles per time unit but represents average sound spectra. It is obvious, that noise barrier acts a crucial role on audible sound spectra (especially high frequencies) therefore additional spectral analysis was performed (Figure 3). The results show the barrier effect on LF at near distances up to \( r \leq 2a \). When the receiver is at \( r > 5a \) distances from noise barrier its attenuation \( \Delta L_{p,oct} < 10 \) dB at very low frequencies which suggests that the use of lightweight barrier is negligible for low frequency attenuation. This is mainly caused due to path length difference \( \delta \).
which is more significant alongside noise barrier. However, better absorption of higher frequencies gives inappropriate spectral balance between low and mid frequencies which can make transportation noise more annoying.

![Figure 3. Sound spectrums of barrier attenuation at various distances](image.png)

The results of low frequency noise measurements and its absolute values in dB in the infrasonic frequency range were compared to the legislation values shown in table 1. As hearing thresholds at infrasonic frequencies are as high as $L_{p,oct} > 70$ dB at 20 Hz and increases as the frequency decrease the measured SPL values were below the threshold by at least 10 dB. This means that infrasonic environment at these frequencies is of acceptable level and should have no negative effect on neighboring agglomerations. Special attention should be considered if the noise barrier is built where the traffic flow contains large amount of heavy vehicles and where these vehicles are accelerating or idling.

As A-weighted sound pressure level represents subjective response to audible frequencies, the G-weighted level is a good indicate for human frequency response to infrasonic and low frequencies. 1/3 octave band frequency spectra was measured at various distances and G-weighted level was calculated. Calculation results are shown in figure 4.

![Figure 4. Calculated G-weighted level at various distances from noise barrier](image.png)

The lowest assessment criteria of 85 dB(G) which shows approximate “threshold” for low frequencies was exceeded only at the source side. Noise level at the receiver side was affected by noise barrier and sound wave diffraction and was of slightly lower level. Our results are similar to those found by Leventhall (2004) and Salt (2010) where wind turbine noise effects were evaluated. However it can be assumed that infrasound of $L_{p,G} \leq 85$ dB(G) should have no effect on human well-being in the agglomerations where lightweight noise barriers are used.

The results of our study expand the knowledge of the use of lightweight acoustic barriers from the perspective of LFN reduction. These barriers are evidently efficient solution for reducing audible frequencies as well as low frequencies and infrasound. It should be considered that the effect of noise reduction mostly depends on barrier dimensions and the distance of the object to the source. Low frequency attenuation was found significant to the distances of approximately 2·a from noise source and negligible at further distances.

However, future work should include LFN spectral analysis in dwelling near such walls because this environment is of special interest yet infrasonic frequencies might be amplified in enclosed spaces.
Conclusions

The level of infrasonic frequencies (f<20 Hz) in the shadow zones of lightweight noise barriers is of average level $L_{p,oct}=75\text{dB}$. This acoustic environment was above threshold value by 30 dB at 6.3 Hz and 10 dB at 20 Hz and should normally have no effect on human well-being.

Spectral low frequency noise content was of unacceptable level at street way only. Calculated low frequency noise level was as high as 92 dB(G) on the source side and lower than 85 dB(G) assessment criteria at the receiver side at any distance.

Lightweight barrier attenuation at distances greater than 5·a is caused by diffraction and can be as high as 5 dB. At distances up to 2·a the barrier noise reduction is approximately 15 dB. This environment should not be attributed as favorable because of inappropriate balance between low, mid and high frequencies of the sound spectra.

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Adhesive Bonding Technology Advanced in the Area of Metal Sheets Bonding

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Abstract

This paper is focused on the necessity of chemical cleaning of the adherent surface, it means the effect of the attachments in the interlayer of the adherent and adhesive. To describe the process of need or absence of chemical cleaning process of adherent surface, that affecting the ultimate strength of adhesive bond, one-component and two-component epoxy resins, polyester resins and cyanoacrylates were used. Laboratory tests of adhesive bond were carried out using the standardized test specimens made according to the standard CSN EN 1465 from the constructional plain carbon steel S235J0, AlCu4Mg, A99.5 and stainless steels.

Introduction

The differences of the production process in the steel metal processing have usually in the particular industrial sectors one common element that is dividing and joining material. Another common element in almost all industrial sectors is considering the following attributes: simplicity and efficiency of the production process. It is also correlative of constant improvement and searching for new technologies. The primary aim is simplicity and speed of the production process. This assumption makes perspectives in the area of adhesive sheet bonding.

Adhesive bonding technology is a prospective joining method of different materials. During this process attachments between adhesive and adherent are created (Müller, 2011). Preserving agents that are applied mainly on the carbon steels (which are susceptible to corrosion) are a significant disadvantage of various shaped sheet products in the bonding area. There was a problem in this area especially in a time of economic recession, when the production of metal sheets was primarily directed to the storage.

When the adhesive bonding theory and the related mechanism of the adhesive bond cohesion are applied, there is coming out a question about the interaction between the adhesion, the adhesive wettability and the cohesion itself, which significantly affect the final strength of the bond. In the respect of the internal structure it is possible to consider each adhesive bond to be a complex of three main layers: bonded material, adhesive and cohesive layer (Müller, Valášek, 2013). The relationship of the above layers affects the adhesive bond strength that can be understood as a property which depends not only on the basic forces by adhesion and cohesion, because there are many other factors that affect the adhesive bond.

This paper is focused on the necessity of chemical cleaning of the adherent surface, it means the effect of the attachments or forces in the interlayer of the adherent and adhesive. This is due to stroke production and waste management in the manufacturing enterprises. In light of stroke production, the technological operations, that deal with surface treatment, are combined or discharged in a many operations. Nowadays are options of using the adhesives limited by economic and environmental aspects.

The important method of mechanical treatment of adherent surface is blasting. This is due to stroke production, quality, variability of abrasive and optimum results of adhesive bonds. In the area of adhesive application the treatment technology of adherent surfaces considered as a dominant. According to the conclusion of the research by many authors it is evident, that the surface structure is very important and reflected the overall ultimate strength of adhesive bond (Naito et al., 2012, Song et al., 2010, Xu et al., 2013, Müller et al., 2013, Müller, 2011). It was also found out that final ultimate strength of the adhesive bond is affected by the type and size of erosion particles.

Experiments confirmed the need for a specific treatment determination of bonding surface, because each mechanical treatment provides another roughness of the bonding surface (Müller, Valášek, 2012). Together with the thickness of the adhesive layer greatly determines the ultimate strength and durability of bond. In the case of inappropriately selected abrasives, erosives, or in the combination with the inappropriate thickness of the adhesive layer, there can be significant decrease of ultimate strength of adhesive bond. Authors Shahid and Hasnic (2002) showed that the most effective method of surface treatment is blasting by abrasive. Chemical, respectively electrochemical surface treatments are important especially to remove impurities from the material surface before the next treatment. These treatments include degreasing, picking, descaling and polishing technology.

With the fact of the adherent surface treatment a research in the field of adhesives which are resistant to this attribute is related.

Materials and Methods

The basis of bonded joints laboratory testing was the determination of the tensile lap-shear strength of rigid-to-rigid bonded assemblies according to the standard CSN EN 1465 (2009).

To describe the process of need or absence of chemical cleaning process of adherent surface, that affecting the ultimate strength of adhesive bond, following one- and two-component epoxy resins, polyester resins and cyanoacrylates were used.

Constructional adhesives on different basis were chosen for the experimental research. The following list presents the identification of tested adhesives and their identification which is used in text for better clear arrangement:
Two-component epoxy adhesive Lepox 1200 (L),
Two-component epoxy adhesive Loctite 7256 Nordbak (LN),
Two-component epoxy adhesive Bison epoxy metal (BEM),
One-component epoxy adhesive Delo Monopox (DM)
Polyester MTB (M),
Cyanoacrylate Alteco Super Glue (ASG),
Cyanoacrylate Super Ceyes Instant Glue Universal (SC),
Cyanoacrylate Loctite Super Bond Power Gel (LSBPG),
Cyanoacrylate Loctite Super Bond Liquid (LSBL),
Cyanoacrylate Distyk Super Glue (DSG).

Specimens of all the tested materials were obtained identically – cutting from the semi-product in the hydraulic guillotine sheet metal machine. Laboratory tests of adhesive bond were carried out using the standardized test specimens made according to the standard CSN EN 1465 (dimensions 100 ± 0.25 x 25 ± 0.25 x 1.6 ± 0.1 mm and lapped length of 12.5 ± 0.25 mm) from the constructional plain carbon steel S235J0, AlCu4Mg, Al99.5 and stainless steels.

For the possibility to compare the impact of specific material treatment on the final ultimate strength of adhesive bond, there is always one set for each of the material without surface treatment. The adhesive bonds were created in accordance to the methodology of manufacturer (i.e. temperature and curing time). The thickness of the adhesive layer was uniform and its size was determined by preliminary tests. Destructive tests were carried out on a test machine loaded with a constant speed of 0.2 to 0.8 mm·min\(^{-1}\), i.e. the failure took place in accordance with the standard CSN EN 1465 during the 65 ± 20 s. Consequently the failure surface was evaluated according to ISO 10365 (1995).

Laboratory experiments focused on the determining the amount of impurities (preservative waxes) were performed on standard specimens made according to standard CSN EN 1465 from the structural carbon steel S235J0, AlCu4Mg, Al99.5 and stainless steel.

The surface of the standard test specimens was not in the first series mechanically or chemically treated before the process of bonding (1) and in the second series it was chemically cleaned in a bath of Acetone P6401 (special organic solvent) (2).

In order to avoid the effect of the same stock and related conservation, there was made a test of the amount of preservatives on the steel, i.e. S235J0 with thickness of 3.1 and 1.5 mm.

It can be assumed that the impurities (especially preservative waxes) on the adherent surface reduce the ultimate strength of the adhesive bond greatly.

The amount of the impurities was determined by weighing. The specimens were not mechanically and chemically treated, and were weighed separately on the laboratory scale. Consequently it was made the chemical surface treatment – degreasing the whole specimen surface by Acetone P6401 and again weighed.

Results

Graphical presentation of the resultant weights of the impurities on specimens that were intended for bonding is presented in box-graph (Figure 1). The results show significant pollution of the carbon structural steel S235J0. This conclusion is a predictable due to the high corrosion potential of this material. During storage and handling it can be assumed high corrosion potential of the environment. Figure 2 shows corrosion fouling on structural carbon steel S235J0 without preservatives placed under laboratory conditions (23 ± 1.13 °C, relative humidity 25 ± 5 %), i.e. for a period of 6 months.

![Figure 1. Determination of the amount of impurities on the specimens intended for adhesive bonding](image-url)
The Tukey’s HSD test was used to compare the statistical average values of the weight impurities on the surface of adherent. The pertinence of each average value to statistically homogeneous groups can be seen in Table 1. Stainless steel and group of aluminium alloys is according to weight of impurities on the surface statistically homogeneous group. Inhomogeneous group are tested two variations of carbon structural steel S235J0 (different suppliers, different thickness). According to above mentioned facts, there was confirmed the assumption of a variable degree of conservation from different suppliers and with depending on the speed of sales.

The average weight of impurities on the surface of material S235J0 was calculated in the case of 3 mm sample at 0.0391 ± 0.0009 g (i.e. 0.007 % of the weight of the sample) and in the case of 1.5 mm sample at 0.00315 ± 0.001 g (i.e. 0.011 % sample weight). Material AlCu4Mg, Al99.5, and stainless steel had less stained with grease in the range from 0.00117 to 0.00156 g, i.e. 0.004 to 0.013%.

Table 1. Statistical comparison of means values - Tukey’s HSD test

<table>
<thead>
<tr>
<th>Metallurgical semi-product</th>
<th>Weight of the impurities on the adherent surface (g)</th>
<th>Agreement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stainless steel</td>
<td>0.001170</td>
<td>*</td>
</tr>
<tr>
<td>Al 99.5, 1.5mm</td>
<td>0.001180</td>
<td>*</td>
</tr>
<tr>
<td>AlCu4Mg, 1.5 mm</td>
<td>0.001560</td>
<td>*</td>
</tr>
<tr>
<td>S235J0, 1.5mm</td>
<td>0.003150</td>
<td>*</td>
</tr>
<tr>
<td>S235J0, 3mm</td>
<td>0.003915</td>
<td>*</td>
</tr>
</tbody>
</table>

Graphic presentation of the results of shear tensile strength of adhesive bonds prepared by ANOVA with method of least squares can be seen from Figure 3. From the results can be seen that higher values of adhesive bond ultimate strength is achieved in the bonds, where the surface has been chemically cleaned. A significant difference was especially in the case of cyanoacrylate adhesives SC, i.e. decrease of the adhesive bond ultimate strength with unclean surface was 58.86 %. A slight increase of the ultimate strength of the specimens with the unclean surface occurred at cyanoacrylate adhesives LSBL (1.75 %). This increase of the strength is the scatter of the results, i.e. 12.35 ± 0.72 MPa and 12.56 ± 0.97 MPa. For other tested adhesives was the decline of strength in the range from 4.89 to 36.3 %. The fracture of the surface was determined identically for all test series (1 and 2) as adhesive type of fracture. Example of the surface fracture is shown in Figure 4.
The Tukey’s HSD test was used to compare the statistical average values of adhesive bond ultimate strength. The pertinence of each average value to statistically homogeneous groups can be seen in Table 2.
Table 2. Statistical comparison of mean values - Tukey’s HSD test

<table>
<thead>
<tr>
<th>Adhesive Designation</th>
<th>Surface Preparation</th>
<th>Adhesive Bond Ultimate Strength (MPa)</th>
<th>Agreement</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>1 2 3 4 5 6 7</td>
</tr>
<tr>
<td>L</td>
<td>1</td>
<td>0.89007</td>
<td>*</td>
</tr>
<tr>
<td>L</td>
<td>2</td>
<td>3.67454</td>
<td>*</td>
</tr>
<tr>
<td>LN</td>
<td>1</td>
<td>4.83684</td>
<td>*</td>
</tr>
<tr>
<td>SC</td>
<td>1</td>
<td>5.12128</td>
<td>*</td>
</tr>
<tr>
<td>BEM</td>
<td>1</td>
<td>7.52249</td>
<td>*</td>
</tr>
<tr>
<td>LN</td>
<td>2</td>
<td>7.59101</td>
<td>*</td>
</tr>
<tr>
<td>BEM</td>
<td>2</td>
<td>8.81478</td>
<td>*</td>
</tr>
<tr>
<td>ASG</td>
<td>1</td>
<td>11.33785</td>
<td>*</td>
</tr>
<tr>
<td>ASG</td>
<td>2</td>
<td>11.92077</td>
<td>* *</td>
</tr>
<tr>
<td>DSG</td>
<td>1</td>
<td>12.12759</td>
<td>* *</td>
</tr>
<tr>
<td>L5BL</td>
<td>2</td>
<td>12.34704</td>
<td>* *</td>
</tr>
<tr>
<td>SC</td>
<td>2</td>
<td>12.44969</td>
<td>* *</td>
</tr>
<tr>
<td>L5BL</td>
<td>1</td>
<td>12.56369</td>
<td>* *</td>
</tr>
<tr>
<td>L5BPG</td>
<td>1</td>
<td>12.67143</td>
<td>* *</td>
</tr>
<tr>
<td>DSG</td>
<td>2</td>
<td>13.71023</td>
<td>* *</td>
</tr>
<tr>
<td>DM</td>
<td>1</td>
<td>14.00578</td>
<td>* *</td>
</tr>
<tr>
<td>L5BPG</td>
<td>2</td>
<td>15.15568</td>
<td>*</td>
</tr>
<tr>
<td>DM</td>
<td>2</td>
<td>18.64617</td>
<td>*</td>
</tr>
</tbody>
</table>

In light of statistic, the series 1 and 2 can be considered as a homogeneous for BEM, ASG, DSG and LSBL adhesive. Most of these adhesives are cyanoacrylates. According to previous data it can be concluded that dependence of the ultimate strength of cyanoacrylate adhesives is not fully on the chemical treatment of steel surface.

Conclusion

Most of the repairs and renovation of machinery and equipments which are used mainly in small and medium-sized farms are made by internal staff. The old agricultural techniques, the effect of degradation processes and also the cost savings are the reasons for the process of repair and renovations. The above mentioned activities have one common element, which are joining methods. Adhesive bonding technology can be understood as a one of the priority joining technology that allows flexibly respond to various geometric shapes (Müller, Herák; 2013). Another significant advantage is the ability to join metallic and non-metallic materials. In practice the most common requirement is to form a joint of various semi-products made by dividing and forming of metal sheets. However it is limited by the need to chemical treatment of surfaces, i.e. degreasing. Below are the conclusions of research on this issue.

The experiments clued-up on determining the changes of bond strength with treatment 1 and 2 were performed on the steel surface, due to the highest contamination grade of impurities on the surface. The quality of a joint can be affected by surface mechanical treatment and accompanying values of surface roughness as well as grease and impurities. However the rate of change of ultimate strength depends on the type of adhesive. The tests showed higher resistance to grade in the case of cyanoacrylate adhesives.

The tests also showed different pollution grade on the surface of the metallurgical semi product.

A major disadvantage of adhesive bonds without mechanical treatment is adhesive failure, it means that the weak point of the bond is the interface of adhesive and adherent. It can be assumed that the cohesive bond strength is not fully utilised (i. e. adhesive strength).

In terms of the production cycle, there is possible to omit the chemical treatment of the adhesive bond and an area of overlap make bigger.

By the design of optimal overlap area it will increase not only capacity of adhesive bond (Müller, Herák, 2010). During the dimensioning of the single-lap joints it is important to consider the use of the maximum load rating of the adherents – with the achieving the yield strength and at the same time utilize the maximum load of adhesive (Müller, Herák, 2010).

The decrease of the ultimate strength of adhesive bond is in the absence of chemical treatment, i.e. the 1 option, in the ranged from 4.89 to 58.86 %, However the average decrease of ultimate strength was about 20 %. This option is useful only in the analyzing the costs and waste management in the area of chemicals management.

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Automation of Solar Energy Appliance as a Supplement for the Residential Building Heating System

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2 Aleksandras Stulginskis University, Lithuania

Abstract

The paper presents one aspect of the smart house, i.e. direction of excess heat collected through solar energy to other rooms of the building with insufficient heating. In our paper we present the automatic regulation of heating system, which generally can be only one aspect of such called smart house system.

In technological point of view, the realization of the smart house includes automation, its adjustment and power supply according the needs of the resident and the residence.

The aim of presented problem is the use of heat excess which is generated in separate rooms of the building (in analysed case due to solar energy). It must be noted that the control system is complicated and continuous power supply must be ensured. By using the autonomous power supply device on the actuation moment the converter load reducing is used. For this purpose electronic circuits with filters are used.

The methodology, suggested in the paper is also acceptable to be used in some building of an older architecture (e.g. open balcony, glassed-in veranda). Scientific novelty – new and integrated solar energy concept developed using reverse automation and continuous power supply. The provided programming case is use of excessive solar energy without solar collection batteries. In our opinion this described method of premises heating realization is one of the ways to economize energy with the least expenses.

Keywords: Smart House, Solar Energy, Reverse automation.

Introduction

Lithuanian rural architecture was and is shaped by social and public phenomena. The construction of the buildings itself is influenced by the purpose of it and available natural resources. The village has been for long time the largest economic entity (Mikelaitis and Jotautiene, 2011). Today the Lithuanian village is different: farms become larger and 3 ha farms dies and the rural tourism develops. In Finland seeking the most wide extensive use of ancient rural buildings and preserve then, they are renovated in the aspects of energy saving and efficient water used (Hinkkanen and Viskari, 2009).

One of the ways to make rural buildings attractive to recreation and tourism is to build them bright and sunny, so that through the big windows the landscapes could be seen. Another question is the heating of such buildings with verandas. The carbon monoxide of discharged pollutants stays in atmosphere for 0.3 of the year (Talubinskas and Puida, 2007).

The most interesting projects for replacing fossil fuels and the reduction of CO₂-emissions are solar systems with seasonal storage in combination with gas or biomass boilers (Fisch et al, 1998). On the other hand, as it is presented by Germany authors, by the integration of seasonal heat storage, more than 50% of the annual heating demand for space heating and domestic hot water can be supplied by solar energy (Schmidt et al, 2004).

On the other hand, glazed and averted to sun rooms quickly heat up then it is rational to use the energy passed through the windows. Or in any other case the temperature of such rooms should be automatically controlled.

The paper presents the heating system, which uses solar energy for additional heating, or the excess of the heating is directed to underfloor. This presented case is the case of rural building, dating the architecture more than 40 years ago. The building was reconstructed with the aim – to catch the maximum of solar energy, as it can be possible in Lithuanian country. Irrespective some particularities of Lithuanian house architecture and the meteorological data, the presented case can provide some technical suggestions for large diapason of countries. For example, even in Turkey comparable heat system experiment was performed from December to May during the heating season (Kaygusuz and Ayhan, 1999).

The paper provides the example of heating automation of veranda, attached to residential house, when due to large number of windows the room additionally is heated up by sun. Underfloor heating in a room, heated up by solar energy is either stopped or directed to other complementary rooms.

The provided programming case is use of excessive solar energy without solar collection batteries. In our opinion this described method of premises heating realization is one of the ways to economize energy with the least expenses. From the other side, this solution is very useful as there is no requirement to change the architecture of the building (e.g. as in case of installation of solar collection batteries), but using already existing heating equipment.

This heating system automation idea is provided in the further paper.

Heat regulation of residential house veranda

In Lithuania heating season for individual houses lasts approximately 6-7 months. Thus the usage of alternative sources for heat energy and reduction of heating expenses is always preferred. This is particularly important during the months of May and September.

Next we look at the case when the excessive heat of individual house veranda after being heated up by sun is directed to other rooms. Figure 1.a) provides schema, where room A is the recreation zone with 40% glazed walls. The
windows of veranda are in the east and south side. The rooms beneath room A – is also recreation zone room B, but with significantly smaller windows. The floor of both rooms is heated by supplying hot water.

The heating of the recreation zones is separated from the heating of the whole house. Later we will develop the idea how it would be possible even at the end of February or at the beginning of March to direct the heat of the rooms, heated up by sun (room A) to room B. This would reduce the costs for the solid fuel, necessary for the heating of the individual house.

As the system must control many valves and circulating pumps, transitions in time and with various retentions must be made. We have to forecast the change of the temperatures both inside the room and outside the building. Thus the program must foresee commutation of devices according to the time of the day. For this task both Germany companies “Kunzel” and “Bosch” collaborate with each other and they prepared a number of automation adjustment applications which can be partially used in our case. However, the provided schemes are dedicated to solid fuel boilers. The paper provides the case of solar energy use using the equipment for room heating. This process is very inert, thus individual programmable control solutions had to be researched. It must be noted that our suggested heat saving solution might be particularly useful in countries with a higher outside temperature.

Here we suggest the heating of one room in the house wing (two floor), and the ventilation of other room (in case of overheating).

The following technical conditions for the realization of heating automation are set. During heating season the temperature of the water which heats the room A is controlled. For the underfloor heating control such room temperature ranges are set:

- If the temperature in room A is >15 °C, then the shutters controlled with allocator electricity is closed.
- If the temperature in room B is >18 °C, then the blinds covering the windows are automatically actuated.
- If the temperature in room A reaches 25 °C ventilation is automatically actuated.
- If the temperature in room A falls to <15 °C, water allocator is closed, so that the water circulating in the system would be heated.

**Direction of excess heat resulting from solar heat to other rooms**

As mentioned above due to large number of windows even during the winter time the room A may heat up to >27 °C. Such temperature already is not comforting also after heating up the floor of the room, the water of the heating system also heats up. Meanwhile the water of the room heated up by solar energy can be directed to room B.

For the control of heating system automation the control of water flow debit considering room’s temperature and automated curtain pulling. Such control of automation is realized by using sequence control and 0 or 1. Virtual programming was performed with Win7 using Grafcet. Grafcet is one of Sequential Function Chart (SFC) programming method (like Petri, statecharts) (Bertrand, 2010). Sequential Function Chart programming defines the sequence of operations, according to the method “state-transfer” (Bertrand, 2010).

In Grafcet program the sequence method will be used and also 0 or 1. That is in the part of Grafcet program the automated control, using functional blocks will be executed depending on set temperature limits. Firstly, the indicating temperature signal 4–20 mA is taken, which for the automat is: 0-10000 (0 = 4 mA, 10000 = 20 mA). Accordingly 4 mA = 0 °C and 20 mA = 50 °C +/-1 °C. Hence it is 1=0,005 °C, though such precision for the automat is unrealistic. Then it results such control values: 15 °C = 3000, 18 °C = 3600, 25 °C = 5000.

The control signal for the valve is: 0–20 mA. The valve is closed with 0 mA and opened with 20 mA. Here information is accepted in respective range of 0–10000. If the room temperature is between 15 °C and 25 °C, it is efficient to control the position of the valve by sequence method, depending on temperature where \( f(t) = t \). The verification and realization of provided programming for the automate Schneider was accomplished using Unity pro v6.

The Figure 2 shows different stages of programming using functional blocks, where information is converted from 4–20 mA to 0–10000 and from 0–10000 to the values according °C.
Figure 2. The presentation of functional blocs for the conversion of information

In Figure 3, in the chart below at the left part of Grafcet, the check is carried out according to the date or if the temperature of room A is higher than temperature of room B. Then it goes to allocator electro valve opening. It allows directing of warm underfloor heating water to room B, thus efficient heat transfer is performed. If the temperature in room B is higher or equal to room A temperature, in such case the allocator valve is closed and heating system pump energy is saved. This is the principle to be as much environmental-friendly as possible.

In the right Grafcet part the extreme temperatures are checked. That is we have the range of comfort temperatures set for us, the authors. This is 15 °C which is cool enough for the room not used at the actual moment. There is also 25 °C as the highest temperature for the room receiving quite a lot of solar energy, which is the subject of the heating system control. In case when in room A this temperature is reached, the valve is open, but also automatically the blinds are pulled to avoid the „overheating“of the room A.

It is known that temperature has big inertia. In such case we set that when the temperature falls below 20 °C the blinds are automatically opened.

Here we reach the most important heating system automation part – i.e. system safety. The case when the sensor is down and control program is working is unacceptable. The control program also must consider solid fuel extreme temperatures due to boiler overheat or extinction. These critical cases are alarmed, automation is stopped and control is functioning again after the reason of fault/critical case is removed.

Automate after receiving the signal below 2000 (sensor problem), acts respectively – the system is switched off. This is one of the biggest advantages for the control circuits with the range of 4-20mA. So, the installation of the buzzer in not the question of the choice, but is the indispensable step in presented programming.

So, it must be noted that the control system is complicated and continuous power supply must be ensured. Thus the autonomous power supply device was created. By using this device on the actuation moment the converter load reducing is used. For this purpose electronic circuits with filters are used (then there are no surges due to inductive load). So for this realisation, the mathematical expression of the function of transfer is implemented as follows (Cottet, 2002):
where, $R_1, R_2$ - resistances, $C_p$ - capacitor.

In our installed system the automated supply actuation time of 70 ms was established (in case of power supply shutdown). As it was defined earlier virtual programming was ensured by defining the conversion “analogue - to numerical”. Practical realization was done using special temperatures sensors which provides some level of resistance (for example, -10 °C represents 760 Ω, +20 °C represents 970 Ω, according to Elfatherm E6) for further control interpretation and automates LOGO of Siemens. The main problems using this automate – low number on Inputs/Outputs (4/4). The range of the indication of the sensors is presented in the table 1.

<table>
<thead>
<tr>
<th>Range of signals for automatic control.</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 mA garbage</td>
</tr>
<tr>
<td>0</td>
</tr>
<tr>
<td>ERROR</td>
</tr>
</tbody>
</table>

It is very clear, that automate is switched off, if the received values are below 2000. Practical experimentation of presented heating system with the use of supplement energy was realized during the May this year.

Conclusions

The programing, which is presented, is only virtual (Figure 2 and Figure 3) of our presented case in Figure 1. The presented case study was tested using reverse automation (automate LOGO of Siemens). However, the data of our experiment 2013 during the May in Kaunas region shows that we have saved energy using solid fuel for heating around 120 kWh per month. Yet more, optimal comfortable heating regime in both rooms (A and B) was ensured. Without this automation it was impossible to ensure normal heating regime for the basement room (room B), despite the fact that the May is already the warm season. The electricity used for control account for about 15 kWh.

The provided programming case is the use of excessive solar energy without solar collection batteries. In our opinion this described method of premises heating realization is one of the ways to economize energy with the least expenses. From the other side, this solution is very useful as there is no requirement to change the architecture of the building (e.g. as in case of installation of solar collection batteries), but using already existing heating equipment.

Acknowledgement. We are grateful to student of University of Artois Paul V. Honvault for charts making and the part of programing, using Grafcet.

References

Adhesive Bonds Mechanical Properties after the Degradation Process

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Abstract

Adhesive bonding technology is dynamically evolving method of the material bonding and that is the reason of its using in the huge range of the industries. In reference to growing evolution, the needs for continuous testing and limits determination of the adhesive bonds grow to keep bonded structures secure. Many producers mention the adhesive resistance to moisture or water in a product list. The research showed that adhesive resistance to liquid mediums is lower and ultimate strength decreases with the exposure time. Experimental data also show that mechanical properties of epoxy adhesives are gradually restored.

Introduction

Development of new types of adhesives extends the application possibilities of bonding technology in the huge range of industries. It is possible to imagine hardly a number of industries without the use of adhesive bonding technology. In a practice it is very important good knowledge about adhesive bonding technology as well as knowledge about factors affecting the ultimate strength of a bond. Strength and durability of the adhesive bond is affected by many factors such as adherent, bond construction, climatic conditions or more precisely environment which affect adhesive bond.

Adhesive degradation can begin during improper storage or with violation of expiration date as pointed Müller and Brozek (2005), these cases can be also treated as a first phase of the adhesive degradation process. Curing process can be treated as a second phase. From the experiments conclusions by Henc et al (2011) it is conspicuous, that lower temperatures make curing process slower and also reduce the strength of the bond. Temperature above a room temperature accelerates the curing process and adhesive strength is higher than under the laboratory conditions.

The third and last phase of the adhesive degradation process is degradation during the life cycle of the bond (it means after the curing of adhesive). Strength limits of the adhesive bonds at the beginning of their life can be reduced by degradation process with the time. On the base of the experiments aimed on degradation process affecting adhesive bonds can be argued that strength of the adhesive bonds is reduced with time and affecting conditions. Decrease of the strength depends on the specific conditions. In a many cases adhesive bonds are exposed to chemical agents or climatic conditions.

Herak et al. (2009) took into account the importance of the different climatic conditions in experiments where effects of the environmental conditions were viewed during eight months (measured with two months step) under the conditions of the tropical climate of Indonesia, specifically in the three regions with different altitudes, daily temperature and relative humidity. In all cases it was found that the strength of adhesive bonds rapidly decreased during the time. The highest and most stable strength values were achieved in Balige, moderate altitude with the "lower" temperature and relative humidity, while the lowest strength was measured in the region of Medan, at sea level with a "high" temperature and relative humidity. In the region of Medan the strength decreased by 76 %. By the prediction of the future process of the bond strength in these areas it was found that in the case of areas Medan and Pagarbatu the strength dropped to zero value till end of one year. In the case of the Balige the strength would reach zero value in about 29 months. Adhesive bonds were not in any stress during the influence of the external conditions. When subjected to a load / stress would be expected results significantly worse.

Doyle and Pethrick (2009) dealt with effect of chemical agents on the strength and durability of adhesive bonds. In experiments they investigated the strength of the adhesive bond, which was under the condition of urea and according to research it is clearly noticeable downward trend of the bond strength. Adhesive bond has about 43% lower strength than at the beginning of the life cycle after two years.

The above aspects affecting the ultimate strength and durability of bonds as was confirmed by Crocombe (1997), who found out that the degradation of adhesive bonds depends on the type of adherent and the type of adhesive, the type of surface preparation of adherent, stress configuration and conditions.

Degradation processes do not affect only the strength and durability of bonds, but very often a mechanism of the bond failure changes of the bonds. Cohesion failure is changed owing to degradation to adhesive, as pointed Taylor and Kinloch (1998). It can be also remarked that degradation process is detrimental to all polymeric materials not only with the plastics based, i. e. adhesives as pointed Müller and Valasek (2011). Due to it, it is essential to test adhesive bonds under specific degradation conditions and subsequent by to determinate their influence on the strength and durability of bonds. As pointed de Silva (2009), every adhesive has a variety of degradation processes with different speeds, and therefore it is very difficult to determine basic prediction equations, which provide strength in different time of the bond durability.

The aim of these experiments was to determine the effect of liquid contaminants on strength changes of adhesive bonds. According to hypothesis it is assumed that constructional adhesives which are resistant to liquid contaminants the adhesive bond strength does not decrease. In case of “yes” it is a question whether this change is reversible.
Material and methods

Experiments were focused on the changes of the mechanical properties of adhesive bonds after the degradation process under liquid conditions. Adhesive bonding technology is used in agriculture for example in the process of bonding wave breakers in the sprinkler containers, due to that fact following degradation conditions: Cererit (fertilizer), water and brine were selected.

After curing the marking of single assessments and placing in the relevant medium followed. Test specimens were immersed into the degradation medium and in the intervals of one month, two months and three months were removed from that medium. After the removing the specimens were placed in a laboratory conditions and part of them was immediately after the removing tested on the Universal testing machine. Other removed specimens were subjected to dehydration. During that time the changes of mechanical properties were determined at the intervals of 24, 72 and 168 hours. Interval “0 hours” means immediately after the removing from the degradation medium after degradation process without dehydration process. Determining of the adhesive bond strength was according to CSN EN 1465.

In the experiments structural epoxy adhesive was used. The adhesive was applied to steel plates S 235J0 with proportion 100 × 25 mm and thickness of 1.5 mm. The procedure of the bonding process was according to CSN EN 1465. Steel plates were firstly mechanically surface treated with blasting by synthetic corundum (Al₂O₃) with size of fraction F80. Than the surface of the sheets was degreased in the Perchlorethylene bath. After the surface preparation adhesive was applied on the steel plate in the width 12.5 mm. To define the thickness of the adhesive between the bonded adherents distance wires with a diameter of 0.11 mm were used. To determine the constant pressure 0.5 kg weight was used.

After the degradation process tensile ultimate strength was observed on a Universal testing machine.

Each cycle was terminated by a destructive testing of the adhesive bonds on the universal testing machine and by defining the failure type according to the ISO 10365.

Result of research

As it was noted, effect of degradation leads to changes of adhesive bond strength limits during a time. The aim of the experiments was to determine the changes of the mechanical properties after the degradation process. The underlying assumption was that diffusion occurs in adhesive bond, which is exposed to liquid condition, and thereby also to the infiltration of liquids into the structure of the adhesive. On this account it can be assumed that after the removing of the specimens from the degradation condition, the liquid will be evaporated and mechanical properties change. The initial tensile strength was 15.23 ± 0.85 MPa.

Figure 1 shows the schematic presentation of the tensile shear strength results of adhesive bonds created by means of ANOVA by the lowest squares methods. Tukey’s HSD test was used for the statistical comparison of mean values. In the Table 1, there are presented single means in the statistically homogeneous groups.

![Figure 1. The effect of environmental degradation and dehydration process on ultimate strength of adhesive bonds](image)
Cererit 1 month, water 2 months, brine 1, 2 and 3 months are statistically homogenous sets from “dehydration” of liquid contaminant (i.e. degradation condition) point of view. Cererit 2 months (inhomogeneity is only during the time of dehydration 0 hours), Cererit 3 months, water 1 month and water 3 months are statistically inhomogeneous sets from “dehydration” of liquid contaminant (i.e. degradation condition) point of view.

According to statistical comparison of homogenous sets, that is data in the Figure 1 and Table 1, it is clear that in a case of liquid contaminant as brine, there are no statistically significant differences in strength of the adhesive bond during the dehydration. In a case of water as liquid contaminant there are significant strength differences in a time 72 and 168 hours of dehydration. Process of dehydration affects most significantly in the case of Cererit.

Table 3. Statistical comparison of mean values - Tukey's HSD test

<table>
<thead>
<tr>
<th>Environment - time of degradation</th>
<th>Dehydration time (hour)</th>
<th>Arithmetical mean (MPa)</th>
<th>Agreement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cererit - 3 months</td>
<td>0</td>
<td>1.16</td>
<td>*</td>
</tr>
<tr>
<td>Cererit - 2 months</td>
<td>0</td>
<td>4.24</td>
<td>*</td>
</tr>
<tr>
<td>Cererit - 3 months</td>
<td>24</td>
<td>4.57</td>
<td>*</td>
</tr>
<tr>
<td>Cererit - 2 months</td>
<td>24</td>
<td>5.41</td>
<td>*</td>
</tr>
<tr>
<td>Cererit - 2 months</td>
<td>72</td>
<td>7.11</td>
<td>*</td>
</tr>
<tr>
<td>Water - 1 month</td>
<td>0</td>
<td>7.24</td>
<td>*</td>
</tr>
<tr>
<td>Cererit - 3 months</td>
<td>72</td>
<td>7.27</td>
<td>*</td>
</tr>
<tr>
<td>Water - 3 months</td>
<td>24</td>
<td>7.32</td>
<td>*</td>
</tr>
<tr>
<td>Water - 2 months</td>
<td>24</td>
<td>7.68</td>
<td>*</td>
</tr>
<tr>
<td>Water - 2 months</td>
<td>0</td>
<td>7.72</td>
<td>*</td>
</tr>
<tr>
<td>Brine - 2 months</td>
<td>72</td>
<td>7.89</td>
<td>*</td>
</tr>
<tr>
<td>Brine - 1 month</td>
<td>0</td>
<td>7.91</td>
<td>*</td>
</tr>
<tr>
<td>Brine - 3 months</td>
<td>0</td>
<td>8.19</td>
<td>*</td>
</tr>
<tr>
<td>Brine - 3 months</td>
<td>72</td>
<td>8.28</td>
<td>*</td>
</tr>
<tr>
<td>Cererit - 2 months</td>
<td>168</td>
<td>8.30</td>
<td>*</td>
</tr>
<tr>
<td>Cererit - 1 month</td>
<td>24</td>
<td>8.34</td>
<td>*</td>
</tr>
<tr>
<td>Water - 2 months</td>
<td>72</td>
<td>8.40</td>
<td>*</td>
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<tr>
<td>Brine - 3 months</td>
<td>24</td>
<td>8.48</td>
<td>*</td>
</tr>
<tr>
<td>Brine - 2 months</td>
<td>0</td>
<td>8.50</td>
<td>*</td>
</tr>
<tr>
<td>Cererit - 1 month</td>
<td>0</td>
<td>8.57</td>
<td>*</td>
</tr>
<tr>
<td>Brine - 2 months</td>
<td>24</td>
<td>8.68</td>
<td>*</td>
</tr>
<tr>
<td>Brine - 2 months</td>
<td>168</td>
<td>8.71</td>
<td>*</td>
</tr>
<tr>
<td>Cererit - 1 month</td>
<td>72</td>
<td>9.23</td>
<td>*</td>
</tr>
<tr>
<td>Water - 2 months</td>
<td>168</td>
<td>9.27</td>
<td>*</td>
</tr>
<tr>
<td>Brine - 1 month</td>
<td>24</td>
<td>9.28</td>
<td>*</td>
</tr>
<tr>
<td>Water - 1 month</td>
<td>24</td>
<td>9.42</td>
<td>*</td>
</tr>
<tr>
<td>Water - 1 month</td>
<td>72</td>
<td>9.42</td>
<td>*</td>
</tr>
<tr>
<td>Brine - 1 month</td>
<td>72</td>
<td>9.65</td>
<td>*</td>
</tr>
<tr>
<td>Brine - 3 months</td>
<td>168</td>
<td>10.22</td>
<td>*</td>
</tr>
<tr>
<td>Brine - 1 month</td>
<td>168</td>
<td>10.40</td>
<td>*</td>
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<td>Cererit - 1 month</td>
<td>168</td>
<td>10.79</td>
<td>*</td>
</tr>
<tr>
<td>Cererit - 3 months</td>
<td>168</td>
<td>10.92</td>
<td>*</td>
</tr>
<tr>
<td>Water - 1 month</td>
<td>168</td>
<td>11.21</td>
<td>*</td>
</tr>
<tr>
<td>Water - 3 months</td>
<td>72</td>
<td>11.34</td>
<td>*</td>
</tr>
<tr>
<td>Water - 3 months</td>
<td>0</td>
<td>11.93</td>
<td>*</td>
</tr>
<tr>
<td>Water - 3 months</td>
<td>168</td>
<td>12.64</td>
<td>*</td>
</tr>
</tbody>
</table>
Conclusion

Dehydration process has a positive effect on the re-increase of strength of the adhesive bond. Liquid contaminants as a water bath, brine and mineral fertilizer have a negative effect on the adhesive bond strength, it is also confirmed by Müller (2013). Action of the liquid contaminants is negative mainly due to the diffuse infiltration in the bond area.

Minimization of the strength losses can be achieved by dehydration process, it means successive regeneration of the polymer chains within the cohesive strength. According to tests it was confirmed that important factor is a type of the contaminant. Implementation of the dehydration process is possible mainly for liquid contaminants, which have not other chemicals, for instance water.

In a time aspect of the liquid contaminants action at adhesive bond strength in the “0” set there is evident decrease in the strength especially in mineral fertilizer “Cererit”. In a case of the water bath and brine growing trend was not confirmed.

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Research of Physical-Mechanical Properties of Sawdust Fuel Briquettes with the Additives

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Abstract

It was investigated the possibility to use the waste of wood – sawdust and waste of biodiesel production – raw glycerol, for production of fuel briquettes. After the analysis of literature it was found, that it was recommended to mix sawdust with the additive – raw glycerol and to produce the fuel briquettes and to use these briquettes for burning. After the research investigations it was determined, that available in the mix optimal amount of glycerol is 20%, and the density of these received briquettes does not exceed 800 kg/m³. It was determined, that after reducing of the glycerol amount, the density of produced briquettes increased, and vice versa. With the increasing of glycerol content from 10 to 30% at the same regimes briquetting, briquettes density decreased from 798±12 kg/m³ to 648±12 kg/m³. And while inserting in the mix 5% of glycerol, the density of briquettes was 1100–1300 kg/m³. It was determined, that the mechanical strength of briquettes depended on the density, and the latter – from the pressed mixture content of sawdust and glycerol. Resistance of experimental briquette for pressure varied from 0.95±0.08 kN (only wood sawdust) to 0.75±0.07 kN (after adding 20% of glycerol to wood sawdust). The same dependences were investigated of experimental briquette for the resistance to crushing. Resistance of pure wood sawdust briquettes for crushing was 95.6±2.5%, and after adding 20% of glycerol – 78.0±1.9 %.

Key words: Sawdust briquettes, additives, raw glycerol, physical-mechanical properties, pressure, density, resistance for crushing.

Introduction

In 2012, about 19.5% of the primary energy was produced from indigenous and renewable energy sources in the country (Raslavicius et al, 2013). It is aimed that renewable energy sources would make about 20–23% of the energy resources in the balance. While producing energy from local and renewable energy resources, the biggest part of energy makes energy from biomass (wood and straw). Using all local energy resources would result in buying less expensive fuel from abroad. As a result, yearly we would save on the average approx. LTL 30 million. Local fuel consumption has also social significance because fuel production, transformation and use require additional working places. It also reduces emissions of CO₂ and SO₂ to the atmosphere.

It is advisable to fire light domestic boilers with wood sawdust briquettes. Most frequently, 50–60 mm diameter circular briquettes with a length of 5–20 cm or square 60 х 60 х 60 mm briquettes are produced (Jasinskas et al, 2012; Strehler, 1983). Many sources indicate density of briquettes from 250 to 600 kg/m³, however, some companies manufactured presses that enable you to prepare sawdust briquettes with density of 1100–1500 kg/m³. The smallest briquette losses are obtained when their density is not less than 750 kg/m³ and their resilience to crumble does not exceed 15 % (Jasinskas and Scholz, 2008; Vares et al, 2007).

While pressing, most commonly additives that connect straw or wood in briquettes are used. Such additives can be clay, manure or other organic bridging material. Up to 9% of such a material is placed into fuel briquettes (Filipezab, 1991). When producing sawdust briquettes, it would be logical to use raw glycerol as a matrix material of rapeseed methyl ester (RME) production by-product. This would reduce the price of biofuel production costs.

Pure glycerol obtained during production of RME may be used in many areas: food, beverages, pharmaceuticals, cosmetics, tobacco, and textile industry (Separating glicerine, 1999). Austiran Institute of Agricultural Engineering started tests in this area (Hahn and Polten, 2002). However, high energy costs are necessary for its production. Such production is profitable if not less than 10 thousand tons / year of raw glycerol are obtained. This quantity is received from production of over 100 thousand tons / year of RME.

The phase of mixing non-separated glycerol with liquid fuel, e.g. mineral oil, and its burning in boilers seems to be the most attractive phase. However, glycerol and other components of the phase are immiscible with petroleum products and get delaminated, so, their usage gets problematic (Ejikeme et al, 2010).

With small production volumes of RME, the most cost-effective way to use glycerol is production of fuel briquettes. The phase of glycerol from which methanol is removed may be used for this. Methanol may create dangerous fire and explosion conditions in briquette production line (Kara, 1996).

Austrian Institute of Agricultural Engineering started tests in this area (Hahn and Polten, 2002). However, in various literature sources, we have not found any record of technological parameters of such briquette production or briquette calorific value. There are no data concerning the maximum possible glycerol content which is possible to include in them, so, we foresee to obtain these and other data from experimental studies.

As it has already been mentioned, chemical composition of raw glycerol and other physical-mechanical properties depend on the RME production technology. Therefore, as a subject of research we chose raw glycerol derived at the REM plant of Agricultural company Telšiai bioenergy. Its properties must be identical to the ones of raw glycerol derived at Limited liability company Rapsoila, because similar phases of rapeseed oil and glycerol separation technology are used at these plants.
Briquetting increases fuel preparation costs. However, the use of such fuels helps to make use of vehicles, moreover, its storage is less expensive. As mentioned above, preparation of fuel briquettes from sawdust using glycerol additive has not been adequately studied. Thus, we plan to conduct such research aiming to use waste of biodiesel production for energy purposes.

**Purposes of the study** – to investigate and substantiate optimal amount of raw glycerol in wood fuel briquettes that affects physical and mechanical properties of briquettes.

**Objectives of the study** – to determine the optimal amount of raw glycerol in sawdust briquettes; to evaluate resistance of fuel briquettes to compression; to determine density, shattering and other physical-mechanical properties of sawdust and glycerol mixture briquettes affecting their use during technological process.

Object and research methods

**Briquette pressing.** An experimental press for fuel briquettes was designed and constructed. The scheme of the press is shown in Figure 1.

![Figure 1. Technological scheme of experimental briquette press: 1 – press camera; 2 – dispenser; 3 – hydraulic cylinder; 4 – air pressure gauge; 5 – hydraulic station; 6 – hydraulic pump; 7 – hydraulic allocator; 8 – electric motor](image)

Compressing sawdust with raw glycerol additive, the mixture was prepared as follows: 5–8% moist softwood sawdust was weighed by electronic balance DS 4 with ± 10 g accuracy. Sample weight was 1 kg. Before mixing, raw glycerol was preheated to 40–45 °C, and poured into sawdust. Samples with raw glycerol additive of 10, 20 and 30% were prepared for pressing. The control sawdust sample was without glycerol. Sawdust was mixed with glycerol manually, and then the sample in a closed container was placed to thermostatic oven, in which constant temperature of 95 ± 1°C was maintained. The sample was held at this temperature for 3 hours so that glycerol could saturate into the sawdust.

While compacting, the developed pressure of the press was measured using a manometer OBMG-1-160 that was connected to the hydraulic cylinders hydraulic fluid hose. Before starting work, pressing camera was pre-heated to 200 ± 5°C by a special 600 W electric heater.

**Determination of optimal raw glycerol amount in briquettes and their resistance to compression.**

According to the above described fuel mixture preparation method, samples with 10, 20 and 30% raw glycerol additive were produced. Prepared samples were pressed into 35 mm diameter and 70 mm high briquettes using laboratory compaction device shown in Figure 2.

![Figure 2. Laboratory compaction device: 1) determination of the biggest amount of raw glycerol incorporation to sawdust briquettes, 2) determination of fuel briquettes’ resistance to pressure force; 1 – frame; 2 – dynamometer; 3 – pressing form; 4 – hydraulic lift; 5 – fuel briquette](image)
The equipment consists of a frame, hydraulic lift with a maximum pull force of 50 kN and a dynamometer DOSM-3-5 for measurements of pressure force. Dynamometer measuring range is 0-50 kN; one interval is 100 N.

Tested fuel mixture is loaded into the pressing form in portions, each time it is compacted by adding the force of about 80 N. After filling the pressing form, the sample was pressed by hydraulic lift up to 50 kN. At the same time, we monitored if glycerol did not start dripping from the form in a space between the wall and pressing plunger. Samples were performed in 5 iterations calculating the arithmetic average of the measured size and the average square error at a probability of 0.95.

**Fuel briquette density** was determined by weighing scales VLTK-500 with ± 0.01 g accuracy; their diameter and length were measured by sliding calipers with a ± 0.5 mm error. Tests were repeated 5 times, and the arithmetic average of the results and the average arithmetic measurement error were calculated (with a probability of 0.95).

**Fuel briquette resistance to pressure force** was determined using a laboratory compaction device (Figure 2). However, instead of a pressing form, a tested fuel briquette was placed between the dynamometer and pressing equipment frame. Research with sawdust fuel briquettes, which contain additive of 10%, 20% and 30% raw glycerol, was carried out. Fuel briquettes resistance to pressure force was set as the arithmetic average after 5 measurements. Pressure was gradually increased till destruction of fuel briquette.

**Briquette resistance to shattering** was determined by a laboratory device which is shown in Figure 3.

![Figure 3. Briquette resistance to shattering device: 1 – rotated box with tested briquettes; 2 – belt gear; 3 – gear; 4 – electric motor; 5 – frame](image)

The device is box-shaped with wire mesh sides. Side length is 400 x 305 x 305 mm. During the experiment, the box is rotated at a frequency of 13 min⁻¹ of its diagonal axis. For the purpose of the experiment, briquettes of the same length are placed in a box. The box with the sample is rotated for 3 minutes. Resistance was set for the briquettes without glycerol and with 10%, 20% and 30% glycerol additive. Percentage of non-shattering briquettes remaining in the box after the experiment was selected as a resistance index (if the remaining briquettes make not less than 20% of the original briquette mass). During a separate test, briquette resistance was calculated according to the formula:

\[ K_u = \frac{M_pr - M_g}{M_pr} \times 100 \]  

where:  
\( K_u \) – briquette resistance obtained during a separate test, %;  
\( M_{pr} \) – briquette mass in device box before the test, kg;  
\( M_g \) – weight of briquettes remaining in the device box after the test, kg.

Before and after the tests, briquettes were weighted by weighing scales VLTK-500 with ± 0.01 g accuracy. Briquette resistance was determined by taking the arithmetic average of five iterations and calculating the mean square error of the measured size at a probability of 0.95.

**Results of research**

**Fuel briquette density.** Visual studies have shown that fuel briquettes with 30% glycerol additive are deformed due to loss of a cylinder form. A better result is found if a briquette contains 20% glycerol. Briquettes with 10% glycerol additive and the ones derived from pure wood sawdust keep correct cylinder shape.

This can be explained by lubrication properties of glycerol that reduce friction of the pressed material into the baling chamber walls, and thus density of the produced briquettes at the same compression force.
Dependence of the obtained briquettes on the composition of the fuel mixture is shown in Figure 4. We may see that density of wood briquettes without glycerol additive was the highest – 861 ± 24 kg/m³. Having added 20% glycerol to briquettes, their density decreased to 742 ± 13 kg/m³, or 1.16 times.

**Figure 4. Fuel briquettes density ρ dependence on glycerol G in the mixture**

Based on the received data, it may be concluded that, when pressing sawdust adding glycerol, it is necessary to adjust the press so that the density of briquettes would not depend on glycerol content thereof. This can be achieved by increasing the resistance to briquetting force, e.g. increasing compression chamber conicity.

**Determination of optimal raw glycerol amount in briquettes.**

Under laboratory conditions, it was found that under operation of the pressed sawdust (8% moisture) and raw glycerol mixture vertical force of 50 kN (pressure of 52 MPa), glycerol is pressed from the mass (if the amount of a mixture is more than 20% (by mass)).

**Briquette resistance to compression.**

Briquette produced by experimental pressing resistance to compression is shown in Figure 5.

**Figure 5. Sawdust briquette resistance to pressure force Pₛ, depending on the amount of glycerol G in the mixture**

As we can see, resistance to pressure force of experimental briquettes is small and varies from 0.95 ± 0.08 kN; that of pure wood briquettes – to 0.75 ± 0.07 kN with 20% glycerol additive. The dependence with the correlation ratio 0.92 can be considered rectilinear.

**Fuel briquettes resistance to shattering.**

Fuel briquettes resistance to shattering based on the equation (1) is shown in Figure 6.

**Figure 6. Dependence of fuel briquettes resistance to shattering Tₛ on added amount of glycerol G**
We see that with increasing glycerol amount in briquettes their resistance to shattering decreases. This is partly explained by the decline of compaction density (see Figure 4).

Conclusions

Having evaluated physical-technical properties of briquettes with raw glycerol additives, it may be stated that, under certain mixture parameters, briquettes completely satisfied requirements for their further use (transportation, storage, incineration) when the glycerol content is not more than 10%.

It was determined that while briquetting sawdust, the amount of glycerol significantly influenced the density of briquettes. With the increasing glycerol amount from 10 to 30% under the same briquetting modes, density of briquettes decreases from 798 ± 22 kg/m³ to 648 ± 12 kg/m³.

Mechanical resistance of sawdust and raw glycerol mixture briquettes depends on their density, and the latter – on the glycerol amount in the pressed mixture. It was determined that resistance to pressure of the produced briquettes changes from 0.95 ± 0.08 kN (without glycerol additive) to 0.75 ± 0.07 kN (after adding 20% glycerol to sawdust).

A similar dependence of the mechanical resistance of briquettes was determined while investigating resistance of briquettes to shattering. At the same pressure, resistance to shattering of pure sawdust briquettes made 95.6 ± 2.5%, and 78.0 ± 1.9% after adding 20% glycerol.

References


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Prospects of Sorghum (Sorghum Moench) Bioenergetic Potential in Ukraine

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1National University of Life and Environmental Sciences of Ukraine  
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Abstract

Research results on energy output with yield of grain and byproducts of sorghum, energy estimation of crop cultivation depending on species, varietal peculiarities, rate of fertilizers application under conditions of right-bank forest-steppe of Ukraine are given in the article.

Introduction

Lack of energy resources, increasingly faced by humanity, is forcing scientists and producers around the world to seek for renewable energy sources. Scientists predict that the products of photosynthesis will cover almost 10% of energy consumption in the future. Modern power producing sector of Ukraine and the EU as well, is largely based on imported raw materials (oil and gas). Price on which constantly increasing, thus, reducing the profitability of businesses and institutions which use these types of energy in production process. Therefore, Ukraine is increasingly working on ways how to use energy produced from renewable energy sources, accumulated through photosynthesis or so called biofuels. This can be achieved through an integrated approach to production, processing and sale of crop production and wide implementation of scientific research results. Thus, there is a need to introduce purposefully in production highly productive crops with high potential, which has been tested worldwide and domestically, and for whatever reason have not received proper distribution. Sorghum Genus crops are highly valuable among energy crops. These crops have high plasticity to growing conditions, are unpretending to weather and are highly productive [1].

Sorghum Saccharatum – is a valuable crop with great potential of yielding capacity, diversity of possible use and plasticity to the environment [2,3]. Today one of the most promising ways of using this crop is renewable energy production. So far as sorghum is not a staple food crop in Ukraine, it is a good raw for solid fuel production and can compete with traditional energy and fuel resources [4]. Sorghum saccharatum provides high biogas output with its green mass yield.

Bioenergetic analysis helps to estimate ratio of energy accumulated in yield due to photosynthesis and energy spent to produce this yield. Because production of biofuel from sorghum become more and more popular, estimation of energy output with yield unit of this crop is doubtfully actual [2,5,6,2].

Increased consumption of sorghum will boost global trade. Exports in MY 2012-2013 are expected to be 7.1 million tons that is 30% higher compared to the current season. The U.S. will account for half of global sales of sorghum, Argentina - 31% Australia - 14%. The share of other countries will be up to 5% of total exports. A total export of sorghum compared to its consumption is only 11%, due to the use of grain for the most part in the domestic markets of producing countries.

In the United States, Mexico, Chile, Brazil, sorghum is a major crop for bioethanol production, providing alcohol output on 25-30% more than that of corn and wheat. Therefore, one of the main factors influencing the price of sorghum is the cost of fossil oil. In addition, global prices on sorghum are directly dependent on the amount of grain on the market.

State program "Ukrainian Grain-2015", developed by the National Academy of Agrarian Sciences of Ukraine and approved in 2011 by the Ministry of Agrarian Policy and Food of Ukraine, is expected to expand in 2015 acreage of millet and sorghum to 500 th. ha (in 2012 projected sowing area of millet is about 234 th. hectares). In this case, with average yield of the crop at 42.1 kg / ha about 2.1 million tonnes of grain will be collected.

Therefore, the aim of our research was to make energy estimation of the different types of sorghum and study the effect of fertilizer application rate on its productivity.

Material and methods

Researches to determine peculiarities of growth and development of different species and varieties of sorghum were conducted on the base of Agronomy research station of National University of Life and environmental sciences of Ukraine (Kiev region, Vasylkiv district, Pshenyche village). Research was conducted under conditions of Right-bank Forest-Steppe of Ukraine. Research was conducted in stationary crop rotation of crop production department of National University of Life and Environmental sciences of Ukraine during 2009-2012. Soil is a black soil typical for Ukrainian forest-steppe. Arable layer contains 4.4 % of humus, pH – 6.87–7.3, cation exchange capacity – 30.7–32.5 mg- equivalent per 100g of soil, bulk density – 1.16–1.25 g/cm3. This soil has comparatively good supply of basic nutrients: nitrogen – 10.6-11.4, phosphorus – 6.2-6.5, potassium – 8.9-10.6 mg/100g of soil.

The climate is mild-continental, yearly precipitations amount is 550 mm, sum of active temperatures above 10 0C about 25500C. The distribution of precipitations and temperatures during vegetation period is not even and significantly varies year by year.
The area of research plots is 25 m² with four time repeat. In our research we use methods approved by State variety testing net and scientific research institutions of Ukraine [4,7].

Research scheme envisages studying of such species and varieties of sorghum as: Sorghum saccharatum – Agrarniy 5F, Krymske 15, grain sorghum – Krymbell, Pamyati Shepelya and Sorghum orizoides – Krypinka 10.

Energy efficiency of technologies was estimated by general energy expenses and energy value of main and byproducts measured with C 200 (IKA) calorimeter [5-7]. Energy output was determined at the stage of full ripeness of grain.

Research results

According to results of our research we established that energy output largely depends on species and varietal peculiarities of the crop and rate of mineral fertilizers. Energy value largely varies depending on part of plant that has been used for analyzes (Table 1).

Table 1. Output of energy from separate parts of sorghum plant per square unit depending on species and varietal peculiarities of plants and fertilization rate, gigacalories per hectare (2007-2009 average)

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</table>

For all varieties of Sorghum saccharatum the highest output of energy was registered in stem. On one hand it can be explained by the high share of stem in general weight of sorghum plant and on the other hand by high energy value of the stem due to high sugar content. Thus caloricity of stem of Krymske 15 variety on control variant of fertilization is 6 times higher than in leaves and 3 times higher than in grain. Sorghum bicolor variety Krymbell and Sorghum orizoides variety Krypinka 10 has inverse correlation – highest calories output on almost all research variants was registered in grain.

In general, energy output was directly proportional to plant productivity. Thus, the highest output of energy was observed on fertilization variant with application of N₁₅₀P₁₂₅K₇₅. The highest sorghum yield was also formed on above-mentioned fertilization variant. Further increase of fertilization rate did not favor accumulation of energy in grain.
Energy expenses for cultivation of sorghum on different research variants varied in between 2.4-7.7 GCal/ha and increases together with increase of fertilization rate (Table 2).

Energy output per unit of research area increased together with the increase of fertilization rate. It can be explained by increase of crop productivity and improvement of soil nutrition regime. The highest output of energy was registered for Agrarniy 5F hybrid of Sorghum saccharatum on variant with application N150P100K60 and made up 201.9 GCal/ha.

Energy output with yield significantly depended on species peculiarities of the crop. Thus, energy output of Sorghum bicolor, Krymbell variety was twice less than that of Sorghum saccharatum, Pamyati Shepelya variety. The same trend was admitted for Sorghum orizoides, Krypinka 10 variety.

Table 2. Energy evaluation of sorghum cultivation depending on species and varietal peculiarities of plants and fertilization rate (2007–2009 average)

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<th>Variety</th>
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<th>Energy output with yield, GCal/ha</th>
<th>Pure energy output minus expenses, GCal/ha</th>
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<td></td>
<td>3.76</td>
<td>29.32</td>
<td>25.56</td>
</tr>
<tr>
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<td>N0P5K45</td>
<td></td>
<td>4.53</td>
<td>32.44</td>
<td>27.91</td>
</tr>
<tr>
<td></td>
<td>N120P100K60</td>
<td></td>
<td>5.30</td>
<td>37.98</td>
<td>32.69</td>
</tr>
<tr>
<td></td>
<td>N150P125K75</td>
<td></td>
<td>6.06</td>
<td>42.11</td>
<td>36.05</td>
</tr>
<tr>
<td></td>
<td>N180P150K90</td>
<td></td>
<td>6.65</td>
<td>38.74</td>
<td>32.09</td>
</tr>
<tr>
<td>Krypinka 10</td>
<td>without fertilizers</td>
<td>1.89</td>
<td>22.45</td>
<td>20.56</td>
<td>6.87</td>
</tr>
<tr>
<td></td>
<td>N0P3K15</td>
<td></td>
<td>2.89</td>
<td>25.02</td>
<td>22.13</td>
</tr>
<tr>
<td></td>
<td>N0P6K30</td>
<td></td>
<td>3.74</td>
<td>29.37</td>
<td>25.63</td>
</tr>
<tr>
<td></td>
<td>N0P5K45</td>
<td></td>
<td>4.59</td>
<td>34.41</td>
<td>29.82</td>
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<tr>
<td></td>
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<td>5.40</td>
<td>38.38</td>
<td>32.98</td>
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<tr>
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<td>N150P125K75</td>
<td></td>
<td>6.15</td>
<td>42.05</td>
<td>35.90</td>
</tr>
<tr>
<td></td>
<td>N180P150K90</td>
<td></td>
<td>6.80</td>
<td>40.38</td>
<td>33.58</td>
</tr>
</tbody>
</table>

Calculated energy efficiency coefficient proves high energy value of each part of this crop for biofuel production. Thus, EEC of Sorghum sacchararum of Pamyati Shepelya variety calculated together with byproducts was two times higher compared to the EEC calculated only for grain.
Conclusions

Based on the results of research we conclude the following:

1. The most energy valuable part of the plant for Sorghum saccharatum varieties Pamyati Shepelya, Agrarniy 5F and Krymske 15 is stem whereas Sorghum bicolor variety Krymbell and Sorghum orizoides Krypinka 10 is grain.

2. Energy efficiency of sorghum increases twice or even more times depending on species and varietal peculiarities of plants if main (grain) and by-products (leaves and stem mass) are used together for energy production.

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Life Cycle Energy Efficiency Indicators of Rapeseed Oil Butyl Esters

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Abstract

Life cycle analysis is one of the methods allowing to classify fuel as biofuel. The main index is energy efficiency indicator, which for biofuel should be equal to 1 or higher. There is no information about life cycle energy efficiency indicators of rapeseed oil butylesters (RBE).

In this study we have analyzed the energy efficiency indicator \( R_1 \) (according to the standards ISO 14040-14049) for RBE, synthesized applying traditional (with NaOH as catalyst) and biotechnological (with immobilized lipase Lypozyme TL BM) methods. The analysis was performed taking into account the rapeseed productivity in Lithuania, European Union and Ireland for different years. The values of energy efficiency indicator \( R_1 \) were compared for rapeseed methylesters, produced by applying the chemical and biotechnological methods.

Introduction

The properties of biodiesel fuel used in the EU should comply not only with the requirements of the standard EN 14214 but also with environmental indicators. Such fuels 90 % of which degrade within 21 days and the life cycle energy efficiency indicator \( R_1 \) of which is greater than 1 are classified as biofuels.

The life cycle analysis is the method that allows evaluating the environmental impact caused by the product or process during its life cycle. Owing to the life cycle assessment, it is possible to determine the energy efficiency, thus comparing total energy consumption for the production, preparation, treatment and processing of raw materials into the final product (fuel). Therefore, the more energy is required for production, the lower the degree of renewability of the fuel is. If a zero or small amount of mineral energy resources is used for the production of fuel, compared to energy derived from the final product, such fuel is considered as fully renewable. The energy efficiency indicator \( R_1 \) is the ratio of the calorific value of biodiesel fuel with the energy demand for its production.

Researchers Raman et al (2011) performed an assessment of the life cycle of the production of biodiesel fuel (palm oil methyl esters) with the use of chemical and biochemical catalysts. The results show that in the case of using immobilised lipase, the negative impact of biodiesel fuel production on the environment decreases compared to traditional methods of synthesis owing to the repeated use of the enzyme preparation. Therefore, they confirmed the results obtained by other researchers (Harding et al., 2007).

Janulis (2004) determined that the values of energy efficiency indicator depend on the country where the raw material grows, climatic conditions, yield and biodiesel fuel production technology. It is known that the indicator \( R_1 \) of fossil diesel fuel is 0.885, while the average corresponding indicator of rapeseed oil methyl esters (RME) is 1.9. Researchers Pleanjai and Gheewala calculated the net energy ratio (NER) of palm oil methyl esters with and without by-products: 3.58 and 2.42, respectively (Pleanjai, Gheewala, 2009). The US researchers established that the indicator of biodiesel fuel (canola oil methyl esters) is 1.78 and that of soybean oil methyl esters is 2.05 (Fore et al., 2011). Data on the efficiency indicators of rapeseed oil butyl esters (RBE) could not be found.

The objective of the research. To evaluate the life cycle energy efficiency indicators of rapeseed oil butyl esters produced by applying biotechnological and chemical methods and to compare them with those of rapeseed oil methyl esters.

Materials and methods

The life cycle analysis involved the application of the methodology provided in the standards ISO 14040-14049. The energy demand in the life cycle of RME and RBE (rapeseed oil butyl esters) was evaluated and compared.

Energy consumption volumes (fuel and energy consumption for the preparation and fertilisation of soil, sowing of rapeseed, harvesting and oil extraction) are presented in the publications of the Lithuanian Institute of Agrarian Economics (The Rates of Mechanised Agricultural Services, 3 parts (Mechanizuotų žemės ūkio paslaugų įkainiai, 3 dalys)), energy accumulated in chemical materials and equipment calculated according to energy equivalents and rates (Velička, 2002; Prueksakorn et al., 2010; Ademe, 1997; Azapour E., 2012). The coefficient 0.876 was assumed in the calculations. In order to evaluate life cycle indicators and energy demands for biodiesel fuel production, the technical data about equipment installed at the enterprise JSC Rapsolia was used. Taking into account the fact that RBE are not produced in Lithuania, a typical RME production technology was selected for the assessment of their production energy consumption.

In order to evaluate the life cycle of rapeseed oil methyl and butyl esters, the life cycle energy efficiency indicator \( R_1 \) was calculated according to the following equation:

\[
R_1 = \frac{E_B}{E_{ac} + E_g},
\]

where: \( E_B \) – calorific capacity of esters, MJ/t of biofuel, \( E_{ac} \) – energy consumption for the cultivation of rapeseeds and their preparation for oil extraction, MJ/t of biofuel, \( E_g \) – energy consumption for the esterification and transesterification, MJ/t of biofuel.

The calorific value of biofuel was determined by using the calorimeter IKA C2000 Basic in accordance with the requirements of the standard DIN 51900.
**Results and discussions**

In order to evaluate and compare the indicators of the life cycle of biodiesel fuel, it is necessary to determine energy consumption at all stages of the life cycle.

**Cultivation.** Taking into account the fact that, in accordance with the data of the Department of Statistics, classical soil cultivation is applied on 68.5% of lands intended for sowing, the ordinary cultivation method was chosen for the calculations. When calculating fuel consumption for cultivation, the data published by the Lithuanian Institute of Agrarian Economics concerning fuel consumption of separate mechanisms for cultivation of 20 ha land plot (Mechanizuotų žemės ūkio paslaugų įkainiai, 2012) and statistical data on the fleet of tractors in Lithuania were used. When recalculating fuel consumption in l/ha, the energy value of 36 MJ/l (43 MJ/kg) for fossil diesel fuel was assumed (according to Directive 2009/28/EC of the European Parliament and of the Council). It was calculated that accumulated energy in fuel consumed for cultivation amount to 1254.96 MJ/ha.

**Sowing.** The preparation of winter rape and the sowing technique are the same as in the case of spring rape. The recommended rapeseed sowing rate: 6 kg/ha. The energy equivalent of rapeseed is 6.22 MJ/kg (Prueksakorn et al., 2010). The energy consumption in rapeseeds is 37.32 MJ of energy. It was established that 3.29 l of fuel is consumed for the sowing of 1 ha of rapeseed, and 118.44 MJ of energy is accumulated in the fuel.

**Fertilisation and treatment with chemical crop protection materials.** Winter rape is fertilised twice: in autumn and in spring. Spring rape is fertilised twice before sowing and also once additionally. It was calculated that fuel consumption for fertilisation when the fertiliser rate exceeds 320 kg/ha amounts to 1.2 l/ha, while energy accumulated in fuel amounts to 43.2 MJ/ha. Winter rape is treated with fungicides, insecticides and herbicides 5 times (before ploughing, before sowing, after sowing and before germination, after sprouting and also once in spring). Spring rape is treated four times (before autumn ploughing, before sowing, after sowing and before germination, and when sprouted) (Velicka, 2002; Kemira Catalogue, 2007). It was found that energy in fuel accumulated for the spraying of spring rape amounts to 114.48 MJ/ha, and that of winter rape amounts to 143.28 MJ/ha. The evaluation of rapeseed harvest showed that in Lithuania, winter rape accounts for 55% and spring rape accounts for 45% on an average. It can therefore be assumed that the average energy consumption for the spraying of rapeseed crops amounts to 130.32 MJ/ha.

**Harvesting.** Combine harvesters are used for the harvesting of rape (the average productivity was assumed in the calculations as 2 t/ha).

Energy consumption in agriculture by rape productivity was recalculated in terms of 1 t of rapeseed. The calculations were based on the actual productivity of rape achieved in Lithuania in 2011 – 1.9 t/ha, the maximum productivity of winter rape achieved in Lithuania during the recent five years – 2.72 t/ha (the Lithuanian Department of Statistics). 2012 rapeseed production in the EU – 3 t/ha (EU Rapeseed: Area, Production Forecast Down from Last Year) and, as the optimistic scenario, the rapeseed productivity achieved in Ireland in 2011 – 4.5 t/ha (Area, yield and production of crops 2011).

Total fuel consumption for the growing of spring rape and winter rape and accumulated energy in agricultural machinery was calculated and presented in the Table 1.

<table>
<thead>
<tr>
<th>Classification</th>
<th>Energy accumulated of agricultural machinery in the growing of rape, MJ/ha</th>
<th>Fuel input, MJ/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1.9 t/ha</td>
</tr>
<tr>
<td>Soil preparation</td>
<td>74.93</td>
<td>1254.96</td>
</tr>
<tr>
<td>Sowing</td>
<td>24.4</td>
<td>118.44</td>
</tr>
<tr>
<td>Fertilization</td>
<td>8.78</td>
<td>43.2</td>
</tr>
<tr>
<td>Insertion of plant protection chemicals</td>
<td>47.66</td>
<td>130.32</td>
</tr>
<tr>
<td>Ingathering</td>
<td>46.41</td>
<td>590.4</td>
</tr>
<tr>
<td>Total</td>
<td>202.18</td>
<td>2137.32</td>
</tr>
</tbody>
</table>

**Energy accumulated in fertilisers and plant protection materials.** One tonne of rapeseed takes from the soil 50–60 kg/ha of nitrogen, 14–30 kg/ha of phosphorus, and 40–90 kg/ha of potassium (Velicka, 2002). However, an amount of substances greater than that taken up by plants is usually introduced in soil. On the basis of the evaluation of the data presented in literature (Kemira Catalogue, 2007, and Velicka, 2002), the average fertilisation rate for the cultivation of rape – N\textsubscript{10}P\textsubscript{8}K\textsubscript{110} – was chosen. The amount of energy accumulated in fertilisers was calculated in accordance with the energy efficiency coefficients of these elements presented in literature (Prueksakorn et al., 2010). In addition to fertilisers, various plant protection materials are used in the growing of rape. When calculating energy accumulated in these materials, the recommendations provided in Kemira Agriculture Catalogue (Kemira Catalogue, 2007) were referred to. The total amount of chemical materials required for the growing of winter rape is 6.4 l/ha, and that for spring rape is 7.9 l/ha. The average amount of the effective substance of plant protection products for the growing of rape is calculated in accordance with the ratio of rape cultivation areas. It amounts to 7.08 l/ha. According to the data of Prueksakorn (2010) (Prueksakorn et al., 2010), the energy equivalent of the chemical substances is 450 MJ/l.

The total energy consumption for seeds, fertilisers and plant protection products amount to 16528.32 MJ/ha.
Total energy consumptions in agriculture for the production of 1 t of RBE, depending on rapeseed productivity – 1.9 t/ha, 2.72 t/ha, 3 t/ha, 4.5 t/ha, - are equal respectively 14370.74 MJ/t RBE, 7055.21 MJ/t RBE, 5816.60 MJ/t RBE, 2616.37 MJ/t RBE.

Figure 1 presents data showing energy consumption (%) in agriculture for the production of 1 t of RBE. It appears that as the productivity of rapeseed grows, energy consumption for the production of one tonne of biofuel decreases proportionally, and the biggest portion of energy consumption falls on fertilisers (68.12–69.57 %, depending on productivity), and the smallest one falls on seeds (0.29–1.58 %, depending on productivity).

![Energy consumption in agriculture (%) for the production of 1 t RBE, depending on rapeseed productivity](image)

**Figure 1. Energy consumption in agriculture (%) for the production of 1 t RBE, depending on rapeseed productivity**

**Energy consumption for industrial processing.** As it has already been mentioned, the second stage of the assessment of the life cycle is to calculate energy consumption for the industrial processing of rapeseeds:
- energy consumption for the transportation of rapeseeds;
- energy consumption for drying;
- energy consumption for oil extraction;
- energy consumption for transesterification.

Energy consumption for transportation amounts to 136.52 MJ of energy, considering the transportation of rapeseeds to the drier (average 20 km) and biodiesel production plant (average 100 km). Energy consumption for rapeseed drying. Rapeseeds to be used for the production of biodiesel must be dried to the standard moisture content of 8 %. In order to obtain 1 t of rapeseeds dried to moisture content of 8 %, it is necessary to remove 8 % of moisture, i.e. to consume 14.8 l of diesel fuel. Recalculated according to the energy equivalent, consumption for drying amounts to 532.8 MJ/t of dried rapeseeds.

Energy consumption for oil extraction and transesterification. In order to evaluate the life cycle energy efficiency indicators of RBE, RME was taken as reference for comparison. It was assumed for the calculations that RME was produced at JSC Rapsoila. To produce 1 t RME at this plant, 3.18 t of dried rapeseed is used. Taking into account the fact that the yield of RBE is 1.14 times greater (owing to a higher molar mass of butanol), 2.79 t of rapeseed is necessary to produce 1 t RBE. Energy consumption for the extraction of oil from rapeseed and transesterification with methanol were taken from the technical documentation of JSC Rapsoila. Energy consumption for transesterification with butanol was calculated in accordance with the established optimal process conditions and on the basis of the data presented in the technical documentation of JSC Rapsoila. It was assumed that RBE would be produced chemically using the same equipment and, after minor modifications and additions, the same equipment would also be used for the production of RBE by applying the biotechnological method. Taking into account the fact that butanol, in contrast to synthetic methanol, is obtained by biotechnological methods, its energy contribution was calculated according to the value of life cycle energy efficiency indicator of butanol – 1.88 (Van der Merwe et al., 2012) and calorific value of butanol.

Energy consumption for the extraction of oil from rapeseed and transesterification with methanol were taken from the technical documentation of JSC Rapsoila. Energy consumption for transesterification with butanol was calculated in accordance with the established optimal process conditions and on the basis of the data presented in the technical documentation of JSC Rapsoila. It was assumed that RBE would be produced chemically using the same equipment and, after minor modifications and additions, the same equipment would also be used for the production of RBE by applying the biotechnological method. Taking into account the fact that butanol, in contrast to synthetic methanol, is obtained by biotechnological methods, its energy contribution was calculated according to the value of life cycle energy efficiency indicator of butanol – 1.88 (Van der Merwe et al., 2012) and calorific value of butanol.

It appears from the data presented in the Table 2 that primary energy accumulated in chemical materials is greater in RBE production when biocatalyst - lipase is used. Energy demand for chemical materials in this case equals to 5741.37 MJ/t, and that in the case of using the chemical method - 4163.77 MJ/t. It is attributable to greater energy accumulated in the bio-catalyst. Compared to biotechnological butyl ester production, 18.84 % more thermal energy and 10 % more electrical energy is consumed in the process of transesterification of rapeseed oil by the chemical method. It occurs so because of higher transesterification process temperature (105 °C) in the production of RBE with the use of chemical catalyst. Total energy consumption in the production of biodiesel by the biotechnological method is 16622.82 MJ/t RBE, and that by the chemical method is 15282.69 MJ/t RBE.
Table 2. Energy consumption for seed squeezing and oil transesterification

<table>
<thead>
<tr>
<th>Classification</th>
<th>Energy input, MJ/t RBE (biotechnological method)</th>
<th>Energy input, MJ/t RBE (chemical method)</th>
<th>Energy input, MJ/t RME (chemical method)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil pressing</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electric power</td>
<td>2188.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heat power</td>
<td>1929.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Primary accumulated in equipment</td>
<td>2289</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>6406.7</strong></td>
<td><strong>4712.22</strong></td>
<td><strong>4553</strong></td>
</tr>
<tr>
<td>Oil transesterification</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electric power</td>
<td>1313.1</td>
<td>1459</td>
<td>1459</td>
</tr>
<tr>
<td>Heat power</td>
<td>1173.07</td>
<td>1445.42</td>
<td>1286.2</td>
</tr>
<tr>
<td>Primary accumulated in equipment</td>
<td>1988.58</td>
<td>1807.8</td>
<td>1807.8</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>4474.75</strong></td>
<td><strong>4712.22</strong></td>
<td><strong>4553</strong></td>
</tr>
<tr>
<td>Energy accumulated in chemicals</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alcohol</td>
<td>3732.57</td>
<td>3732.57</td>
<td>3015</td>
</tr>
<tr>
<td>Catalyst</td>
<td>2008.80</td>
<td>251.10</td>
<td>195</td>
</tr>
<tr>
<td>Phosphoric acid</td>
<td>0</td>
<td>180.1</td>
<td>180.1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>5741.37</strong></td>
<td><strong>4163.77</strong></td>
<td><strong>3390.1</strong></td>
</tr>
<tr>
<td>Grand total</td>
<td><strong>16622.82</strong></td>
<td><strong>15282.69</strong></td>
<td><strong>14349.8</strong></td>
</tr>
</tbody>
</table>

Table 3 represents the data of total energy consumption both in agriculture section and rapeseeds squeezing and oil transesterification, according to the rapeseeds productivity and transesterification method.

Table 3. Energy consumption in agriculture and industry to produce esters, depending on production method and rapeseeds productivity

<table>
<thead>
<tr>
<th>Rapeseeds productivity, t/ha</th>
<th>Energy consumption for rapeseed cultivation, MJ/t biofuel</th>
<th>Energy consumption for seed squeezing and oil transesterification, MJ/t biofuel</th>
<th>Total, MJ/t biofuel</th>
</tr>
</thead>
<tbody>
<tr>
<td>RBE production (biotechnological method)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.9</td>
<td>15353.58</td>
<td>16622.82</td>
<td>31976,40</td>
</tr>
<tr>
<td>2.72</td>
<td>7741.76</td>
<td></td>
<td>24364,58</td>
</tr>
<tr>
<td>3</td>
<td>6439.07</td>
<td></td>
<td>23061,89</td>
</tr>
<tr>
<td>4.5</td>
<td>3031.35</td>
<td></td>
<td>19654,17</td>
</tr>
<tr>
<td>RBE production (chemical method)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.9</td>
<td>15353.58</td>
<td>15282,69</td>
<td>30636,27</td>
</tr>
<tr>
<td>2.72</td>
<td>7741.76</td>
<td></td>
<td>23024,45</td>
</tr>
<tr>
<td>3</td>
<td>6439.07</td>
<td></td>
<td>21721,76</td>
</tr>
<tr>
<td>4.5</td>
<td>3031.35</td>
<td></td>
<td>18314,04</td>
</tr>
<tr>
<td>RME production (chemical method)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.9</td>
<td>15957.29</td>
<td>14349,80</td>
<td>30307,09</td>
</tr>
<tr>
<td>2.72</td>
<td>8045.35</td>
<td></td>
<td>22395,15</td>
</tr>
<tr>
<td>3</td>
<td>6691,31</td>
<td></td>
<td>21041,11</td>
</tr>
<tr>
<td>4.5</td>
<td>3149.23</td>
<td></td>
<td>17499,03</td>
</tr>
</tbody>
</table>

Energy efficiency indicators on the basis of the obtained results with regard to the production method and rapeseed productivity are presented in the Figure 2.

![Figure 2. Comparison of life cycle energy efficiency indicators depending on the production technology and rapeseed productivity](image-url)
As it appears from the data provided, even in case of a lower rapeseed productivity (1.9 t/ha), the life cycle energy efficiency indicator of RBE, with the application of both the biotechnological and chemical methods, is greater than 1. It means that such biofuel can be classified as renewable.

Conclusions

The life cycle energy efficiency indicator (R) directly depends on rapeseed productivity.

The life cycle energy efficiency indicator of rapeseed butyl esters, with the application of both the biotechnological and chemical methods, is greater than 1 when rapeseed yield is 1.9 t/ha and higher. It means that such biofuel can be classified as renewable.

Life cycle energy efficiency indicators of RBE and RME differ insignificantly given the same rapeseed productivity. When productivity is 1.9 t/ha, R of RME is 1.22, R of RBE produced by the chemical method is 1.24, and that of RBE produced by the biotechnological method is 1.19.

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Effect of Solar Radiation on Thermal Performance of External Wall Structures Based on Long-Term Measured Data

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Abstract

This paper discusses some of the factors affecting the energy consumption of different external wall structures in northern climate. The studies have been conducted at the Department of Civil Engineering at Tampere University of Technology (RTEK/TUT) during the past 16 years. As one of the outputs measured data from 6 test buildings (plus six-year data from additional 2 test buildings) has been built up. The level of detail (520 sensors in each building), amount (after each 20 seconds), long-term (measuring period of six and ten years) and coherency (measured at the same time at the same conditions) makes that data unique in Finland as well as in Europe.

Up to 50% differences were found in the measured and calculated heat losses. Possible reasons for such a discrepancy are described and discussed. It has been focused on the effect of solar gains to thermal performance of massive exterior wall structure. Examples from massive external brick leaf (cladding) of the insulated brick wall are demonstrated. The thermal energy from solar radiation stored in the cladding during daytime warms the air in the ventilation gap and has a great momentary impact on the need to compensate heat losses. Due to the high thermal inertia of the brick leaf temperature of the inner surface of the leaf facing the air gap remains relatively high until early evening. This advantage is not available throughout the year, but its impact is much greater than usually believed.

The knowledge from this study forms the base for the design and construction of sustainable external wall structural solutions. The location of the test buildings is showing a significant impact of solar radiation and thermal inertia to the thermal performance of external wall structures in Tampere, Finland. As the average solar radiation increases towards the south, the effect is expected to be greater in Baltic states.

Keywords: Test buildings, external walls, energy consumption.

Introduction

Research in the field of energy need and efficiency of buildings is very actual, urgent and rapidly developing. A great amount of models and simulations on the energy consumption in buildings have been developed and improved. Some review of the current status in research is provided by the following journal papers. The accuracy of energy analysis and for modern, well-insulated Nordic buildings in Nordic climate has been studied (Kalema et al., 2008). Calculations by seven researchers and by seven different calculation programs were compared. Six of these programs were simulation programs (Consolis Energy, IDA-ICE, SciaQPro, TASE, VIP, VTT House model) and one monthly energy balance method (Maxit energy) based on the predecessor of standard EN ISO 13790. The study showed that the differences in input data cause often greater differences in calculation results than the differences between various calculation and simulation methods (Kalema et al., 2008). A Round Robin Test (Tronchin and Fabbri, 2010) was performed to compare, test and validate the several existing typologies of building energy simulation tools, provided that the same data input and typology of calculation model are given. The Round Robin Test included all modern energy calculation methods. The results of test show the relationship between thoroughness of data input and energy evaluation accuracy. The more the input data is affected by uncertainty, the less precise is the energy efficiency calculation (Tronchin and Fabbri, 2010). Therefore, previous research has shown that inaccurate input data leads to inaccurate results in calculation of energy consumption of buildings. Guan (2009) has been concluding that since all building simulation programs require hourly meteorological input data for their thermal comfort and energy evaluations, the provision of suitable weather data becomes critical.

Therefore, the aim of the following experimental study is to solve an urgent scientific demand for: a) accurate measured data and b) appropriate input for building energy simulation programs.

The Department of Civil engineering at Tampere University of Technology (RTEK/TUT) has gathered ten-year (Sept. 1997 – Aug. 2007) long measured data from six test buildings. Six-year (Apr. 2001 – Aug. 2007) data from additional two test buildings is also available. The data was collected from identical-sized test buildings, having different commonly used exterior wall structures in Finland. A computer system (data logger) was used to monitor, check, calculate, integrate, and save the data acquired from approximately 520 sensors in each building were applied in data recording. Measurements were taken with a time interval of 20 seconds. The 20 second values were then integrated over a time interval of 30 minutes and the minimum, maximum, and mean values were subsequently stored to a computer database.

Six test buildings were constructed in a moderately exposed parking area within the compound of Tampere University of Technology (Fig. 1). Later on two more test buildings were constructed. Test buildings shield one another from the outdoor winds. The surrounding of the test buildings can be considered mostly as rural.

The external walls of the test buildings were constructed of different building materials that include: polyurethane insulated wooden frame wall (T-B 1), insulated cavity brick wall (T-B 2), insulated log wall (T-B 3), plastered massive brick wall (T-B 4), autoclaved aerated concrete (AAC) block wall (T-B 5), and log wall (T-B 6). The ceilings and floors of all the test buildings were composed of two layers of foamed polyurethane elements with an overall thickness of 200 mm. External doors were installed within the eastern wall and the test buildings had no windows. The floor area of each test building was 2.4 m × 2.4 m and the free floor to ceiling height was 2.6 m. Fig. 2 shows the details (section) of the external wall structures of the test buildings.
Figure 1. Test buildings at RTEK/TUT

All the test buildings are heated with a 1500 W electric radiator (1248 mm × 400 mm heat panel) except for the massive brick wall test building, which is heated by two 1200 W electric radiators (1008 mm × 400 mm heat panels). During the heating season the indoor air temperature inside the test buildings was constantly maintained at 20 °C. Test buildings number 1, 3, and 5 were ventilated by balanced mechanical ventilation systems with heat recovery. Test buildings number 2, 4, and 6 were ventilated by exhaust mechanical ventilation system. The air change rate in all the test buildings was 0.5 h⁻¹. For occupancy simulation, (2 g/m³) moisture content was constantly added to the indoor air. The additional moisture content was provided by continuously heating water that was kept into plastic containers inside each test building.

A weather observation station was constructed at the test buildings’ site that measures the outdoors temperatures, wind speed, and direction, and the relative humidity of the air. The intensity of solar radiation was also measured on-site by a pyranometer (solar meter) that was fixed on the eaves level of test building number 5. The pyranometer measures the global solar radiation to the building surface, which is composed of the direct, and the diffused solar radiation. Wind speed and direction were measured 10 m high from the ground using an anemometer that was fixed to a steel mast at the test building number 5. A three-cup anemometer was used to measure the wind speed whilst a wind streamer monitored the wind direction.

Figure 2. Details of the external wall structures of the test buildings
In addition, temperatures inside the wall structures were monitored at different depths in order to determine the temperature distribution in the walls. Airflow rates and temperatures of the supply and exhaust air were continuously monitored. The temperatures were measured with calibrated semiconductor sensors and copper–constantan thermocouples. The indoor relative humidity was monitored with two humidity sensors. The number of semiconductor sensors and thermocouples were about 350 and 170, respectively.

Multiplexers were used to collect the data from the sensors so that readings from each channel were recorded to a computer after every 20 s. Analog-to-Digital and Digital-to-Analog (ADDA) cards were used for data collection and conversion. The minimum, maximum, and average values from the 20 s measured values were saved to a computer hard disc after every 30 min. The relative humidity inside the wall structures of the northern and southern facades were measured to determine the moisture content of the wall materials and the rate of drying after construction. The air tightness of the test buildings was measured by pressurization test method at 50 Pa pressure difference while infiltration was measured using tracer gas.

Results and discussion

Through the analyzed period from September 1998 to May 1999 the measured (light blue bars) heat losses through the external walls of test buildings were up to 50% smaller than calculated (light blue + dark red bars; Fig. 3) (Lindberg et al., 1998; Lindberg and Leivo, 2005).

![Figure 3. Measured (light blue bars) and calculated (light blue + dark red bars) heat losses of the walls of test buildings at TUT from Sept. 1998 to May 1999 (Lindberg et al., 1998)](image)

There are three main reasons for the difference between measured and calculated energy consumption: (1) the material properties from which the U-values are calculated, (2) the areas of the walls, and (3) the solar radiation energy stored in the external part of the exterior walls (Lindberg and Leivo, 2005; Lindberg et al., 2008).

(1) The U-values are calculated from the thermal conductivity (λ) values of the materials. The design thermal conductivity values can be obtained from declared values, measured values or (in the absence of before mentioned) tabulated values (EN ISO 10456:2007). Measured thermal conductivities of materials form a distribution as all other material properties. For the calculation of a U-value, a design thermal conductivity λ value at the upper end of the distribution is chosen. It is clear that when the aim is actual energy consumption, the real thermal conductivity of materials should be used. The difference between the average thermal conductivity and the thermal conductivity value used to calculate the U-value is quite large with some of the thermal insulation materials used.

(2) The amount of heat energy lost through an exterior wall is linearly dependent on the wall area. In the exterior wall of a building, the area can be based on internal or external dimensions, or some area in between. Differences between the areas are large due to the thickness of the insulation. Traditionally areas based on the external dimensions of insulations have been applied. A principle from the viewpoint of design allows providing sufficient heating power for each room with view to the coldest possible situations. Various calculation models apply the areas based on external dimensions. Analysis of the measurement results shows that actual consumption should be evaluated based on dimensions close to internal dimensions. For instance, the higher energy consumption at an outside corner is reduced by the decreasing temperature difference around the corner area. The internal section of the corner has a lower temperature than inside air while the external sections have a higher temperature than the outside air. This smaller temperature difference thereby reduces energy consumption (Lindberg et al., 2008).

(3) A key factor is the effect of the solar gains of the massive exterior wall structure in saving heating energy. In principle the effect can be found from Fig. 3 i.e. the ratio between calculated and measured heat losses is larger with
massive solid external wall structures (1.5-brick (T-B 4); AAC (T-B 5); log (T-B 6)) and external walls with massive external leaf (brick + insulation (T-B 2)). The effect of solar gains is lost in exterior wall structural solutions, where thin and lightweight material (timber cladding) is applied as an outer leaf (polyurethane T-B 1; log + insulation T-B 3).

Fig. 4 shows the dependency between the outer surface temperature of the external brick leaf of the insulated brick wall (T-B 2) and the measured solar radiation at the site during late February 2005. Correlation between the measured solar irradiance at the site and the measured surface temperature of the brickwork is evident. Fig. 4 also illustrates that the effect of solar radiation to outer surface of the structure is much stronger than to ambient outdoor temperature. The average ambient outdoor temperature during the period was $T_{\text{out,ave}} = -9.3^\circ \text{C}$, and the average surface temperature during the same period was $T_{\text{surf,ave}} = -5.2^\circ \text{C}$, which is 44% less than the outdoor temperature (Lindberg et al., 2012).

Figure 4. Measured solar irradiation at the site, the ambient outdoor temperature and the measured outer surface temperature of brick leaf in late February 2005 (Lindberg et al., 2012)

Figure 5 shows the measured temperature distribution inside the wall structure during a 24-h period on 27 February 2005. The maximum measured outdoor temperature of the day was $T_{\text{out,max}} = -6.4^\circ \text{C}$ at 15:02 (Figure 4). Meanwhile, the measured surface temperature of the outer brick leaf was $T_{\text{surf,out}} = +17.9^\circ \text{C}$ (at 15:02, Figure 4) and the temperature of the inner surface of the brick leaf $T_{\text{surf,in}} = +14.7^\circ \text{C}$. Temperature difference between the ambient air and inner brick surface was $\Delta T = 21.1^\circ \text{C}$. This temperature difference has a significant effect on the actual heat loss through the insulation layer, as shown in measured temperature distribution curves (Fig. 4).

Due to the high thermal inertia of the brick leaf temperature of the inner surface of the leaf facing the air gap remains relatively high until early evening though the outer surface temperature of the leaf had already decreased significantly. At 21:00, the measured ambient outdoor temperature was $T_{\text{out}} = -13.1^\circ \text{C}$, temperature of the outer surface of the brick leaf $T_{\text{surf,out}} = -7.5^\circ \text{C}$ and the measured temperature of the inner surface of the leaf $T_{\text{surf,in}} = -3.6^\circ \text{C}$. The difference between the surface facing the air gap and the ambient air was still $\Delta T = 9.5^\circ \text{C}$.

The ventilation gap air is generally assumed to be of the same temperature as outdoor air and, therefore, the external leaf (cladding) is ignored in the calculations. Previous examples are showing that this assumption is wrong with external wall structures with massive outer leaf due to its thermal inertia. The thermal energy from solar radiation stored in the cladding during daytime warms the air in the ventilation gap and has a great momentary impact on the need to compensate heat losses. This advantage is not available throughout the year (not during the time period from November to January), but its impact is much greater than usually believed.
Fig. 4 and 5 have shown that the outer surface temperature of the walls is much different from outdoor air temperatures during sunny days. That difference could be significant in any sunny day from late February until September. In that sense, outer surface temperature is much more accurate input for the building energy simulation. Applying outer surface temperature would result in much more accurate calculations of building energy consumption.

Applying outer surface temperature would result in much more accurate calculations of building energy consumption.

The principles also apply for roof structures to which the effect of the solar radiation is even greater. In this respect as an innovation, efforts should be made for applying phase-changing materials (PCM) in light-weight structures of buildings (e.g. wooden frame walls). PCMs, which by melting and solidifying at a certain temperature, are capable of storing and releasing large amounts of energy. Heat is absorbed or released when the material changes from solid to liquid and vice versa.

The northern location (latitude 61°25’N) of the site of the test buildings shows that the solar radiation and the thermal inertia of the different structural sections of an external wall have a significant effect on the actual heat loss and energy consumption. As the average solar radiation increases towards the south, the effect of solar radiation on building structures is expected to be greater in Baltic states. For the time being much of the gathered data is still under-utilized. Further analysis on the long-term hygrothermal behavior of different external wall structures is still needed.

Conclusions

The Department of Civil Engineering at Tampere University of Technology (RTEK/TUT) has gathered ten-year measured data from 6 test buildings (plus six-year data from additional 2 test buildings). The level of detail (520 sensors in each building), amount (after each 20 seconds), long-term (measuring period of six and ten years) and coherency (measured at the same time at the same conditions) makes that data unique in Finland as well as in Europe.
The analysis of the results have been revealed up to 50% difference between measured and calculated heat losses. Three main reasons for the difference were found: (1) the material properties from which the U-values are calculated, (2) the areas of the walls, and (3) the solar radiation energy stored in the external part of the exterior walls. Examples from massive external brick leaf (cladding) of the insulated brick wall are demonstrated. The thermal energy from solar radiation stored in the cladding during daytime warms the air in the ventilation gap and has a great momentary impact on the need to compensate heat losses. Due to the high thermal inertia of the brick leaf temperature of the inner surface of the leaf facing the air gap remains relatively high until early evening. That difference could be significant in any sunny day from late February until September. Due to the same effect the outer surface temperature is much higher than outdoor air temperature. Therefore, outer surface temperature could be much more appropriate input in order to increase the accuracy of calculations of building energy consumption.

References


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The use of Oilseed Meal for the Production of Biogas

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2National University of Life and Environmental Sciences of Ukraine

Abstract

The article presents the results of the studies of using oilseed meal for biogas production. In laboratory conditions, biogas was produced from oil extracted from turnip rape, oil flax, fodder rape, white mustard, brown mustard, oilseed rape, winter tifon, sunflower, and chufa sedge. The results have shown that the greatest amount of biogas (0.81 m^3 kg^-1 DM) and the highest concentration of methane (68.64%) are obtained from oil flax meal. The meal of all the studied seeds, except for mustard, can be used for biogas production, and rapeseed meal and chufa sedge meal are most promising of them and allow obtain the biggest amount of biogas. It amounts to 0.64 m^3 kg^-1 DM and 0.59 m^3 kg^-1 DM, respectively, and exceeds the amount of biogas obtained from sewage sludge. It is not reasonable to use white mustard meal and brown mustard meal for biogas production because sulphur compounds present in them result in a low yield of biogas, while the content of methane is only 49–54%.

Introduction

Recently, interest in renewable energy sources and their efficient use has been growing. This is caused by decrease of fossil resources, rise in their prices and environmental pollution with greenhouse gases.

In order to reduce environmental pollution with greenhouse gases, the Kyoto Protocol was signed, whereby most Member States of the EU, including Lithuania, envisaged reducing the amount of exhaust gases by 20% until 2020 compared to 1990. The expansion of the use of renewable energy sources in the EU is promoted by various legal and regulatory documents.

The transport sector is one of the major polluters of the atmosphere with greenhouse gases. The global average share of pollutants emitted from transport vehicles into the environment amounts to around 13%, while in Lithuania the corresponding rate is as high as 35.5%. This prompted the adoption of Directive 2009/28/EC of the European Parliament and of the Council, which encourages the Member States of the EU to increase the consumption of biofuels and to seek that biofuels replace 10% of all fuels consumed in the transport sector by 2020.

Currently, there are two main types of biofuels used in the transport sector: bioethanol – in blends with gasoline, and biodiesel – in blends with fossil diesel fuel. The production of biodiesel involves the use of vegetable oil. Its type depends on the region. In the United States, the most commonly used type of vegetable oil is soybean oil; in Europe, it is rapeseed oil and sunflower oil; in Indonesia and Malaysia – palm oil.

In Europe, the majority of biodiesel (84%) is produced from rapeseed oil, while sunflower oil accounts for 13% of the raw materials used for production (European Biomass Industry Association). Soybean oil, palm oil and oil of other kinds so far accounts for only 1% of the total amount of raw materials used. However, in a situation of the lack of food-grade rapeseed oil and increasing competition between the food and non-food sectors, new types of oil and other oleaginous raw materials for biodiesel production are sought.

Vegetable oil is extracted from oilseeds by the mechanical pressing or extraction methods. Cake (when pressing with mechanical presses) or meal (when extracting oil with chemical solvents) are left as by-products. They are most commonly used as components of feed for livestock and poultry; however, because of their chemical composition and properties, such use of rapeseed cake or meal is limited (Thiripathi and Mishra, 2007).

Other utilisation options have to be sought. Biodiesel production results in the formation of not only cake and meal of oilseeds, but also glycerol and free fatty acids. Free fatty acids are returned to production and are esterified with alcohol in obtaining biodiesel. Glycerol and cake or meal can be used for biogas production, while effectively using obtained gas for own production heat and electricity needs or transport.

Biogas production usually uses agricultural or municipal waste: animal manure and sewage sludge. By applying the of anaerobic fermentation process, a mixture of gases containing about 50–70% of methane is obtained. Besides, biogas contains 25–45% of carbon dioxide, a small amount of hydrogen, hydrogen sulphide and oxygen (Karellas et al, 2010).

In order to enable effective use of gas in engines, carbon dioxide and hydrogen sulphide are removed from them. Other types of raw materials used for biogas production, in addition to animal manure and sewage sludge, include food industry and agricultural waste (Yadvika et al, 2004). In Germany, biogas production from maize silage is widespread and the use of various herbal plants is considered.

The use of glycerol for biogas production has been studied. It was found that a 4% additive of raw glycerol in pig manure increases the yield of biogas four-fold (Astals et al, 2012), while the opportunities of the use of meal or cake were not studied sufficiently. Some authors studied the opportunities of the use of castor cake alongside with other raw materials (Lingaiah and Rajasekaran, 1986; Gollakota and Meher, 1988; Sumitra Ramachandran et al, 2007).

Oleaginous seeds differ from each other by their physical and chemical properties; therefore, the yield of biogas and production efficiency can also be different. The objective of our research was to evaluate the properties of various oilseed meals and their suitability for biogas production.
Materials and methods

Oilseeds were harvested at the Experimental Station of the National University of Life and Environmental Sciences of Ukraine. The following seeds were taken for the research: turnip rape ((wild turnip) (*Brassica rapa var. oleifera*), oil flax (*Linum usitatissimum*), fodder radish (*Raphanus sativus*), white mustard (*Sinapis alba*), brown mustard (*Brassica juncea*), oilseed rape (*Brassica napus*), winter tifon (*Brassica napus*), sunflower (*Helianthus annuus*), and chufa sedge (*Cyperus esculentus*).

Oil from the seeds was extracted with hexane using a Soxhlet apparatus; before the use, seeds were ground using a mill IKA Werke MF 10 basic. Extracted oil was used for the production of biodiesel fuel, and the meal remaining after extraction was heated at a temperature of 100 °C for 5 h to evaporate the hexane. The quality indicators of the seed meal were established in accordance with the requirements of Directives 71/393/EEC and 72/199/EEC.

Studies of biogas production from the meal of oleaginous plants seed were carried out in graduated 100 ml plastic syringes placed into a thermostatically controlled shaker. The biomass was decomposed in a mesophilic environment at a temperature of 37 °C. 30 ml of spent substrate after biogas production (taken from AB Kauno Vandeny) and 0.25 g of defatted oilseed biomass was used for each study. The mixture was blended thoroughly and the homogenised mass was placed into the syringe. The duration of biogas production was 32 days. Amount of biogas generated was measured every day. The composition of biogas was determined by using gas chromatograph Perkin Elmer Clarus 500 – Arnel 4017 once during the biogas production period. The results of biogas production from the meal of oleaginous plants seed were compared with the reference results of biogas production from sewage sludge.

Each experiment was performed twice and the following was evaluated: average values, standard deviation, standard error, coefficient of variation and the true value of the value measured.

Results and discussion

The studies involved oilseeds which are characterised by high oil content and which have potential for biodiesel production. After extracting oil from oilseeds, meal was obtained and then used for biogas production studies. The physical and chemical properties of defatted meal are presented in Table 1. All the samples had roughly the same oil content (2.9% to 3.1%). Protein content differed significantly ranging from minimum in chufa sedge meal (8.6%) to maximum in fodder radish meal (40.2%). Chufa sedge meal showed the highest fiber content (56.3%), while the smallest amount of fiber was found in brown mustard meal (Table 1).

Table 1. Composition of oilseed meals

<table>
<thead>
<tr>
<th>Oilseed</th>
<th>Protein content, %</th>
<th>Oil content, %</th>
<th>Fiber content, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turnip rape</td>
<td>35.5</td>
<td>3.0</td>
<td>11.5</td>
</tr>
<tr>
<td>Oil flax</td>
<td>38.4</td>
<td>2.9</td>
<td>8.7</td>
</tr>
<tr>
<td>Fodder radish</td>
<td>40.2</td>
<td>3.1</td>
<td>12.5</td>
</tr>
<tr>
<td>White mustard</td>
<td>36.4</td>
<td>3.0</td>
<td>7.9</td>
</tr>
<tr>
<td>Brown mustard</td>
<td>38.9</td>
<td>3.1</td>
<td>7.7</td>
</tr>
<tr>
<td>Oilseed rape</td>
<td>33.7</td>
<td>2.9</td>
<td>13.4</td>
</tr>
<tr>
<td>Winter tifon</td>
<td>29.3</td>
<td>2.9</td>
<td>11.3</td>
</tr>
<tr>
<td>Sunflower</td>
<td>24.1</td>
<td>2.9</td>
<td>31.5</td>
</tr>
<tr>
<td>Chufa sedge</td>
<td>8.6</td>
<td>3.0</td>
<td>56.3</td>
</tr>
</tbody>
</table>

The yield of biogas depends on the composition of raw material. Taking into account the fact the meals had almost the same fat content, it was sought to evaluate the impact of the amount of protein and fiber and their mutual relationship in meals on the yield of biogas. The results of the studies of biogas yield are presented in Figure 1. They show that the greatest amount of biogas was produced when oil flax meal was used for anaerobic digestion. It also demonstrated the highest rate of biogas production: around 90 % of biogas was obtained during the first 15 days of fermentation. The maximum amount of produced biogas was 0.81 m³ kg⁻¹ of dry matter (DM) of oleaginous meal.

The most intensive biogas production from meals of all types, except for mustard and turnip rape, was observed during the first 5 days. Winter tifon seed meal ranked second in terms of the amount of formed biogas. Compared to sewage sludge which is ordinary used for biogas production and which generates 0.57 m³ kg⁻¹ DM biogas, oilseed rape meal and chufa sedge meal were also characterized by a greater amount of biogas obtained: 0.64 m³ kg⁻¹ DM and 0.59 m³ kg⁻¹ DM, respectively. However, the use of oil flax meal was considerably more beneficial and the yield of biogas increased as much as 1.4 times compared to sewage sludge.

The yield of biogas from sunflower meal equals to the yield obtained from sewage sludge, while fodder radish meal, white mustard meal and brown mustard meal produced a lower yield of biogas compared to sewage sludge. Biogas from turnip rape meal was produced at a lower rate; however, the yield reached its maximum within a period of 25 days and did not differ significantly from the amount of biogas obtained from sewage sludge. The biogas production process with the use of white mustard meal and brown mustard meal showed different trends. During the first days, the amount of biogas produced was close to zero and the yield began to slowly increase after 11 days. Only on the 29th day,
the yield of biogas from brown mustard meal reached almost the same level as that received from sewage sludge; however, such yield could not be obtained when using white mustard meal. On the last day of the studies, a yield of only 0.47 m$^3$ kg$^{-1}$ DM biogas was recorded.

**Figure 1. Yield of biogas from different oilseed meals**

Biogas production is a complex which involves as many as four groups of bacteria. The yield and composition of biogas depends on the composition of the substrate used for its production. The highest yield is produced by fat, lower yield is received from hydrocarbons, and the lowest is generated by fiber. However, our studies showed that only the evaluation of the composition does not allow predicting the yield of biogas. Oil flax meal and mustard meal were characterized by a similar protein and oil content and their mutual relationship; however, the yield of biogas differed by as much as 1.7 times. Besides, the biogas production process in the case of mustard meal was delayed and maximum was reached only during the last days of the studies, while biogas production from oil flax meal showed the highest speed during the first week of the studies. It can be attributed to the presence of other substances in meal, which possibly condition the vitality and activity of bacteria. It is known that mustard contain a lot of sulphur compounds – isothiocyanates which have a bactericidal effect and are able to inhibit the activity of bacteria involved in biogas production.

**Table 2. Methane and carbon dioxide content in biogas obtained from oilseed meals**

<table>
<thead>
<tr>
<th>Oilseed</th>
<th>CH$_4$, %</th>
<th>CO$_2$, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turnip rape</td>
<td>66.78</td>
<td>33.73</td>
</tr>
<tr>
<td>Oil flax</td>
<td>68.64</td>
<td>31.65</td>
</tr>
<tr>
<td>Fodder radish</td>
<td>68.47</td>
<td>31.49</td>
</tr>
<tr>
<td>White mustard</td>
<td>49.42</td>
<td>50.57</td>
</tr>
<tr>
<td>Brown mustard</td>
<td>54.33</td>
<td>45.66</td>
</tr>
<tr>
<td>Oilseed rape</td>
<td>65.84</td>
<td>34.04</td>
</tr>
<tr>
<td>Winter tifton</td>
<td>65.48</td>
<td>34.51</td>
</tr>
<tr>
<td>Sunflower</td>
<td>64.91</td>
<td>35.08</td>
</tr>
<tr>
<td>Chufa sedge</td>
<td>64.38</td>
<td>35.61</td>
</tr>
<tr>
<td>Sewage sludge</td>
<td>68.49</td>
<td>31.50</td>
</tr>
</tbody>
</table>

Methane content in biogas is the most important indicator of the quality of biogas and its suitability for the use for energy needs. It is impossible to avoid carbon dioxide during the formation of biogas; however, it must be removed in order to enable the use of biogas in the transport sector. Carbon dioxide is removed by different methods, most commonly, by those based on sorbtion. Methane and carbon dioxide content in biogas obtained from oilseed meal is presented in Table 2. The highest methane content (more than 68%) was shown by biogas obtained from oil flax meal and fodder radish meal. The content of methane in that gas exceeded the content in gas obtained from sewage sludge. Slightly lower methane content (around 65%) was found in biogas obtained from other oilseed meals, except for mustard meal. White mustard meal and brown mustard meal produced the lowest methane content, which amounted to 49.42% and 54.33%, respectively. The content of carbon dioxide in biogas obtained from white mustard exceeded the content of methane. The results of the composition of biogas proved the fact that the fermentation process of mustard meal differs from that of other oilseed meals studied. Sulphur compounds inhibit the activity of methanogenic bacteria, fail to process carbon dioxide synthesised by less sensitive acetogenic bacteria in them and the methanogenesis process occurs feebly.

To summarise the obtained results, it can be stated that the most promising type of oilseed meal for the use in biogas production in oil flax meal which produce the highest yield and methane content. Oilseed rape meal and chufa
sedge meal can also be supplied to bioreactors because a lower content of methane in gas is offset by a higher yield of biogas compared to the use of sewage sludge. These raw materials could be supplied to bioreactors together with sewage sludge. Their addition would not decrease the yield of biogas and methane content. Mustard (both white and brown) meal has absolutely no prospects in biogas production. Their use produces both a low yield of biogas and low methane content in gas.

Conclusions

Oilseed meal can be used for the production of biogas. During anaerobic digestion, it produces an amount of biogas similar to that obtained from the ordinary raw material – sewage sludge.

Oil flax meal shows the greatest potential for biogas production: they allow producing 0.81 m$^3$ kg$^{-1}$ DM with methane content of 68.64 %.

The amount of biogas obtained from oilseed rape meal and chufa sedge meal is 0.64 m$^3$ kg$^{-1}$ DM and 0.59 m$^3$ kg$^{-1}$ DM, respectively. This amount exceeds the amount of biogas obtained from sewage sludge. Such meal could be supplied to bioreactors together with sewage sludge.

White mustard meal and brown mustard meal is not suitable for biogas production because of the presence of sulphur compounds in them. They result in a low yield of biogas, while methane content is only 49–54 %.

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Impact of Rapeseed Oil on Characteristics of the Engine Tractor Zetor 8641 Forterra

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CULS-Czech University of Life Sciences Prague

Abstract

The European Union currently pays great attention to the possibilities of the use of biofuels to power mobile machinery. The main reasons for the promotion of biofuels is the effort of Member States to reduce dependence on oil imports, efforts to reduce emissions from internal combustion engines and also efforts to support agriculture. The most common is currently using methyl rostliných oils because of their vlastbnosti closely resembles conventional diesel. Their production is energy intensive. Therefore, as a preferable alternative seems to be used directly vegetable oils. The use of vegetable oils is limited in particular viscosity and density. Therefore, in the paper evaluated the proportion of vegetable oil (rapeseed oil) in diesel in proportions 5.5 and 19.7%, to avoid engine damage. Evaluated the emission components of carbon dioxide (CO2), carbon monoxide (CO), hydrocarbons (HC), nitrogen oxides (NOx) and particulate matter (PM) and fuel consumption. A higher proportion of rapeseed oil in the fuel mainly reflects the increase in specific fuel consumption and carbon dioxide.

Keywords: biofuels, emissions, fuel consumption.

Introduction

In recent years, the European Union has devoted increasing attention to the possibilities of the use of biofuels in the power mobile machinery. The main requirements for biofuel demand is the similarity of its chemical and physical properties with the traditional fuel.

As the best substitute for the diesel fuel, which covers most of the energy consumption of agricultural equipment, the fatty acid methyl esters (FAME) are currently being promoted. Specifically in the Czech Republic, the most common substitute for the diesel oil is the Rapeseed Oil Methyl Ester (RME). Although the RME is chemically different from petroleum products, its fuel properties such as density, viscosity, calorific value and combustion process, the diesel is very close (Table 1). Requirements for the diesel fuel are specified in the standard ČSN EN 590 [4] and the RME requirements prescribes the standard ČSN EN 14214 [3].

Based on the requirements of EU directives implementing the mandatory addition of the RME (or other methyl) in the diesel fuel to the maximum volume fraction of 7 %. This blended fuel complies with the ČSN EN 590 [4] and can be used without any modification in the existing diesel engines. The mixed diesel according to the ČSN 65 6508 indicates the fuel which consists of the diesel and the RME (at least 30 % - "Biodiesel II. Generations").

Another option is to use the vegetable oil (rapeseed oil). The idea is to use it to drive machines originated in 1895 when Rudolf Diesel invented the diesel engine. Currently, mainly two views on propulsion engines using vegetable oil are widespread.

Engine engineers and technicians refuse to address this issue (damage to both the pump and the engine). In their opinion, they are supported by enthusiasts who pour vegetable oil into the tank without any modifications or they use an unprofessionally rebuilt diesel engine. The vegetable oil is denser than the oil and its viscosity is higher (Table 1). There are basically two ways to reduce the viscosity:

- chemically - so do the manufacturers of the RME,
- by heating – by heating the vegetable oil strong increase its fluidity can be achieved. [5]

The crude oil can be poured directly into the diesel engines without major modifications. It has got a higher viscosity than the normal petrol, which doesn’t cause a real problem when it is used in the areas with a higher temperature. Thanks to the higher oxygen content, the engine has got more power under full load than that of diesel. Some systems can be divided into two fuel tanks. The engine is started and stopped using the mineral oil. There may be used a specially modified engine. Unlike the diesel, the biodiesel is very biodegradable (within 21 days the degradation is around 90%), contains almost zero of sulfur and heavy metals, and generally is low in emissions. [2, 6, 8, 13]

Properties of the oil, particularly its quality and density, are important for production of the biodiesel (Table 1). Generally, it is necessary to reach small oil contamination, low acid number, low levels of phosphorus, water and ash particles and to increase its oxidative stability. [1, 7, 8] In addition to the requirements of engine fuels must also meet the design requirements such as resistance materials, adhesive joints, etc. [9, 10, 11]

The aim of this paper is to compare the influence of different types of fuels containing bio-characteristics on the tractor engine (they were chosen different mixing ratios of the biofuel and the diesel). These characteristics were measured for fuel consumption, Carbon dioxide (CO2), carbon monoxide (CO), hydrocarbons (HC), nitrogen oxides (NOx) and particulate matter (PM). As the fuel for the engine of the tractor Zetor 8641 Forterra (less than 100 mth) blends of the diesel fuel with the bio fuel were used (the percentage indicates the proportion of the biocomponent and the rest is complemented by a clean diesel):

- 5.5 % of the repassed oil,
- 19.7 % of the repassed oil (higher share of biofuels can not be used due to a significant change in viscosity and density of the fuel).
Table 1. Comparison of basic parameters of the diesel fuel (ČSN EN 590), RME (ČSN EN 14214) and rapeseed oil

<table>
<thead>
<tr>
<th>Request</th>
<th>Diesel</th>
<th>Repassed oil</th>
<th>RME</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density at 15 °C (kg.m⁻³)</td>
<td>820 - 860</td>
<td>915</td>
<td>860 - 900</td>
</tr>
<tr>
<td>Kinematic viscosity at 40 °C (mm².s⁻¹)</td>
<td>2,0 - 4,5</td>
<td>35</td>
<td>3,5 - 5,0</td>
</tr>
<tr>
<td>Freezing Point (°C)</td>
<td>-4 / -22</td>
<td>-8 / -20</td>
<td></td>
</tr>
<tr>
<td>Flash Point (°C)</td>
<td>over 55</td>
<td>246</td>
<td>over 120</td>
</tr>
<tr>
<td>Cetane number</td>
<td>min. 51</td>
<td>38</td>
<td>min. 51</td>
</tr>
<tr>
<td>Calorific value (MJ.kg⁻¹)</td>
<td>42,5</td>
<td>36</td>
<td>37,1 – 40,7</td>
</tr>
<tr>
<td>Carbon residue (% by weight)</td>
<td>0,10 - 0,30</td>
<td>max. 0,3</td>
<td></td>
</tr>
</tbody>
</table>

Material and methods

The fuel system of the tractor was not constructed for fuels containing repassed oil. To the rear PTO of the tractor Zetor 8641 Forterra (Table 2 and Fig. 1) a hydraulic dynamometer AW NEB 400 was attached (Table 3 and the Fig. 1). To the fuel system was was added a tractor fuel measuring device, which contains two flowmeters Macnaught MSeries FLOWMETER M2ASP-1R (1 % accuracy). Another sensors were used to measure the engine oil temperature, air temperature, fuel temperature and air pressure. For the smoke measurement purposes, the BrainBee analyzer was used (Table 4 and Fig. 2). [12].

Table 2. Basic technical parameters of the tractor Zetor Forterra 8641 (according to manufacturer)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated engine power ECE 24 (kW)</td>
<td>60</td>
</tr>
<tr>
<td>Rated speed (1/min)</td>
<td>2200</td>
</tr>
<tr>
<td>Maximum torque (Nm)</td>
<td>351</td>
</tr>
<tr>
<td>Specific consumption at rated power (g / kWh)</td>
<td>253</td>
</tr>
<tr>
<td>Maximum overspeed speed (1/min)</td>
<td>2460</td>
</tr>
<tr>
<td>Idle speed (1/min)</td>
<td>750</td>
</tr>
</tbody>
</table>

Table 3. Basic technical parameters of the dynamometer AW NEB 400

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum torque on PTO (Nm)</td>
<td>2850</td>
</tr>
<tr>
<td>PTO - Maximum speed (min⁻¹)</td>
<td>3200</td>
</tr>
<tr>
<td>Maximum braking power (kW)</td>
<td>343</td>
</tr>
<tr>
<td>Maximum braking power at a speed of 540 1/min PTO (kW)</td>
<td>149</td>
</tr>
<tr>
<td>Measurement error (%)</td>
<td>2</td>
</tr>
</tbody>
</table>

Table 4. Parameters of smoke analyzer Brainbee

<table>
<thead>
<tr>
<th>Component</th>
<th>distinction</th>
<th>accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO</td>
<td>0,01 % vol.</td>
<td>0,03 % vol. or 5 % RV (read value)</td>
</tr>
<tr>
<td>CO₂</td>
<td>0,1 % vol.</td>
<td>0,5 % vol. or 5 % RV</td>
</tr>
<tr>
<td>HC</td>
<td>1 ppm vol.</td>
<td>10 ppm vol. or 5 % RV</td>
</tr>
<tr>
<td>O₂</td>
<td>0,01 % vol.</td>
<td>0,1 % vol. or 5 % RV</td>
</tr>
<tr>
<td>NO</td>
<td>1 ppm</td>
<td>10 ppm vol. or 5 % RV</td>
</tr>
<tr>
<td>Opacity</td>
<td>0,1 %</td>
<td>2 %</td>
</tr>
</tbody>
</table>

Figure 1. Dynamometer AW NEB 400

Figure 2. Smoke analyzer Brainbee
At first, the external rotation speed characteristic was measured. This characteristic is measured when the PTO is turned on, the full supply of the fuel is left during the whole measurement. Since the dynamometer at this point still does not draw any braking torque, the engine speed reaches the maximum amount. After the start of the measurement, the dynamometer load will be increased and will be reflected in decrease of the engine speed. The data on torque, engine power, engine speed, fuel consumption and other measured variables were recorded at regular intervals during the speed decrease.

Furthermore, based on the external speed characteristic (Fig. 3), the eligible measuring points for creation a complete engine characteristic (Fig. 4) were chosen. The measuring points (about 35-40) are determined so that the most of them belong to the engine working space. After switching on the PTO shaft, the dynamometer was set-up, as well as the engine operational conditions, so that the engine became stabilized at the desired operating point. After fixing, the engine operation, its speed, torque, power, fuel consumption, smoke etc. were recorded.

The torque values measured on the dynamometer PTO are converted – by using the appropriate gear ratio (3.543) – into the torque moment of the engine. To compare the impact of the fuel on the engine characteristics, the losses of the engine don’t influence the PTO shaft, and therefore these are not considered. The resulting values of the specific fuel consumption and individual components of the emission therefore correspond to the engine power at the PTO shaft.

The measured values were then processed by using the MathCad program functions into the form of continuous surfaces. To create the continuous surfaces, the functions REGRESS and INTERP were used. The function REGRESS in conjunction with the interpolation function INTERP (1) approximates the preset polynomial fits of the measured points in the fuel consumption. The PlochaZ in the coordinates of the PlochaXY represents the coordinates of the rotation speed om and the torque moment TM. The result of the fitting is a continuous variable Plocha(om, TM). From this surface, the 41x41 square matrix (1,681 points) is created to be used for further processing. This matrix of the 1,681 points is then further processed using the interpolation function SPLINE (2), which interleaves the area precisely defined by the points in the 41x41 matrix. At the same time it is possible to get information on any point outside the matrix.

\[
\begin{align*}
R & := \text{regress}(\text{PlochaXY}, \text{PlochaZ}, 3) \\
\text{Plocha}(\text{om}, \text{TM}) & := \text{interp}\left[R, \text{PlochaXY}, \text{PlochaZ}, \begin{pmatrix} \text{om} \\ \text{TM} \end{pmatrix}\right] \\
\text{Plocha}(\text{om}, \text{TM}) & := \text{interp}\left[\text{cspline}(\text{PlochaXY}, \text{Plocha}), \text{PlochaXY}, \text{Plocha}, \begin{pmatrix} \text{om} \\ \text{TM} \end{pmatrix}\right]
\end{align*}
\]

\( \text{PlochaXY} \) matrix giving the coordinates of the speed \( \text{om} \) and the torque moment \( \text{TM} \)

\( \text{PlochaZ} \) column of the data processed - variables (eg. fuel consumption) (g.h\(^{-1}\))

\( 3 \) polynomial of the 3rd degree (optional)

\( \text{Plocha (om, TM)} \) continuous variable area (g.h\(^{-1}\))

\( \text{Plocha} \) the matrix of the measured values in 1681 points (g.h\(^{-1}\))

\( \text{om} \) coordinates of the rotation speed (min\(^{-1}\))

\( \text{TM} \) coordinates of the torque moment (Nm)

Results

Based on the methodology presented above, the external speed characteristics (Fig. 5) of the tractor Zetor 8641 Forterra were successively measured. The fuel composition in the engine tank was changed in these experiments. The measured data were processed and mathematically interpolated by the continuous function SPLINE (similar results can
be achieved for LOESS functions REGRESS - MathCad 14), to make available the engine torque value for any rotation speed.

Figure 5. **Performance parameters - Rapeseed oil**

Full engine characteristics were measured for fuel with 5.5 and 19.7% rapeseed oil. At the same time, the overall characteristics created for all the components of emissions and fuel consumption. Example of complete engine characteristics is given on the fuel consumption and at the same time shows the point of minimum specific fuel consumption in the Fig. No. 6. Also for other emission component was found and shown in Fig. No. 7 and 8, the point with the minimum production.

Figure 6. **Complete engine characteristics of operating on rapaseed oil 19.7%**

Figure 7. **Points of minimal specific production of watched folders - 5.5% rapeseed oil**
From Fig. 7 and Fig. 8 shows the lower minimum points produced components in fuel consumption and carbon dioxide was achieved when the fuel containing 5.5% of rapeseed oil. Fuel with 19.7% of rapeseed oil was improved in the production of nitrogen oxides and carbon monoxide. Hydrocarbons and particulate matter in both cases were identical with regard to the accuracy of the measuring method. In terms of the distribution of individual points can be stated that the point of minimum specific fuel consumption, nitrogen oxides, sulfur dioxide and smoke is used for both mixed fuels in the same area. Paragraph minimum specific production of hydrocarbons and carbon monoxide is the same load, but differ in the speed at which it was reached.

Conclusion

For the measurements of the engine of the Zetor 8641 Forterra tractor with the attached PTO hydraulic dynamometer AW NEB 400 was used. By using the dynamometer, the individual points to create a complete engine characteristics. For recording the fuel consumption, the fuel box with two fuel gauges Macnaught MSeries FLOWMETER M2ASP-1R was explored.

From Fig. 7 and Fig. 8 shows the lower minimum points produced components in fuel consumption and carbon dioxide was achieved when the fuel containing 5.5% of rapeseed oil. Fuel with 19.7% of rapeseed oil was improved in the production of nitrogen oxides and carbon monoxide. Hydrocarbons and particulate matter in both cases were identical with regard to the accuracy of the measuring method.

The disadvantage of the use of the fuels with a higher proportion of biofuels are mainly due to the higher maintenance demands put on the fuel system, lower engine power and greater fuel consumption. In contrast, the advantage of using biofuels is higher lubricity and reduction of emissions and very good biodegradability against the diesel.

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The Influence Ethanol–Diesel-Biodiesel Blends on Performance and Emissions of Off-Road Diesel Engine

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Aleksandras Stulginskis University, Lithuania

Abstract

The paper presents comparative analysis of the performance and emission characteristics when operating on various ethanol-diesel-biodiesel blends at various loads and engine speeds. The experimental tests were performed on a four-stroke, four-cylinder, direct injection, naturally aspirated, 60 kW diesel engines D-243. The in-cylinder pressure data was analysed to determine the ignition delay, the heat release rate, maximum in-cylinder pressure and maximum pressure gradients. The influence of ethanol-diesel–biodiesel blends on the brake specific fuel consumption and exhaust emissions was also investigated. The bench test results showed that when the engine was running on blends B15 and B15E at low loads and 1800 min\(^{-1}\) speed, the autoignition delay was 5% and 12% longer than that measured as a straight diesel. The maximum cylinder pressure and pressure gradients decreased by about 1–9 % with the increasing amount of anhydrous ethanol in the diesel fuel when operating at low load. When the engine load increased, the maximum cylinder pressure increased for all blends. The brake specific fuel consumption of blends B5–B15E increased by 1.6 and 8.9% for moderate and full loads, respectively, compared to the normal diesel fuel. The brake thermal efficiency decreased by 1.5%, and 4.7%, respectively, for the same operating conditions. The NO\(_x\), HC emissions decreased and CO emissions increased when operating on oxygenated blends B15 and B15E.

Keywords: diesel engine, ethanol, rapeseed methyl ester, autoignition delay, performance, emissions, opacity of the exhaust.

Introduction

The internal combustion engine is one of the main users of fossil fuels. Currently, diesel fuel is among the most popular vehicle fuel types. The demand of diesel fuel has been growing constantly during the last two decades. The increase in diesel fuel demand can be explained by the fact that diesel engines are more efficient, use relatively less fuel per engine effective power unit and have a less harmful impact on the environment compared to gasoline engines. However, limited reserves of fossil fuels, increasing market price of mineral fuel and ambient air pollution create problems and impose researchers to investigate a new alternative and renewable energy resource suitable for diesel engine powering.

The chemical and physical properties of the ethanol-diesel-biodiesel blends change the fuel injection, atomization and combustion characteristics and thus the exhaust emissions. In case of ethanol-diesel blends, the common problem is that the ethanol and diesel fuel phase separation can occur during storage (Torres-Jimenez, et. al., 2011). Due to the differing chemical and physical properties of ethanol and diesel fuel, having mixed these two components, it is possible to monitor how the diesel fuel goes down to the bottom after some time and the ethanol sustains on the top of the canister. The phase stratification time depends on the amount of water in the ethanol and the percentage of ethanol in the diesel fuel. The larger is the amount of ethanol in the diesel fuel and the lower is ambient temperature, the quicker these two fractions stratify.

When the amount of ethanol increases in the diesel fuel, the cetane number (CN) of the blend decreases about proportionally because the cetane number of ethanol (8) is significantly lower than that (51.5) of the diesel fuel. However, the autoignition delay of diesel fuel, especially in case of using synthetic biofuel, is not always directly dependent on the cetane number only (Labeckas, G., Slavinskas, S., 2013). The autoignition delay time depends also on the environment created within the engine cylinder, i.e. varies with gas pressure and temperature in the combustion chamber. Significant influence on the autoignition delay have also such factors as combustion chamber design, compression ratio, chemical structure of the fuel and injection characteristics, which affect the quality of combustible mixture and temperature level in the cylinder at the end of the compression stroke.

The calorific value of ethanol is lower compared to the diesel fuel. The net calorific value of diesel fuel is 41.8–44 MJ/kg and that of the ethanol is about 27.22 MJ/kg, therefore, the net calorific value decreases and brake specific fuel consumption increases because of addition of the ethanol to diesel fuel, (Torres-Jimenez, et. al 2011; Erkal, G., 2010). It should be noted that the brake thermal efficiency of biodiesel slightly increases for most load and speed conditions due to positive effect of the fuel oxygen fraction increased in diesel fuel despite the higher brake specific fuel consumption than that of a strait diesel. According the scientific study (Weber de menezes, E. et al., 2006), the higher brake thermal efficiency developed by the engine results from a higher oxygen mass (wt%) fraction in the blend that contributes to complete combustion of the mixture. Viscosity of the diesel fuel significantly reduces after mixing of it with alcohol additives. When the viscosity of biofuels (ethanol) is too low, it can increase the wear of plunger-barrel and needle-valve-body precision surfaces. It is possible to increase the fuel viscosity by using ethanol-diesel-biodiesel (RME) blends (Armas, O. et. al., 2011). The addition of ethanol to diesel fuel significantly reduces the flash point, so the use of biofuel blends increases the fire emergency.

The authors of studies (Rakopoulos, D. C., 2008; Sendžikienė, E. et. al., 2006) showed that the use of ethanol and other oxygenated additives reduces the amount of nitrogen oxides in the exhaust through more homogeneous flammable mixture and thus lower combustion temperature (Hansen, A.C. et. al., 2006). The analysis of other works (Di, Y., 2009) shows that the amount of unburned hydrocarbons noticeably increases due to addition of the ethanol to diesel fuel because of the longer autoignition delay. However, the results obtained by other researchers (Arapatsakos, C., 2009) show that the quantity of unburned hydrocarbons decreases for the higher ethanol percentage in the blend that
can be related to the larger amount of oxygen available for complete combustion. The ethanol adding to diesel fuel reduces also the carbon monoxide CO in the exhaust (Lu, X. et al., 2008).

The aim of the research was to investigate the autoignition delay and combustion processes of the engine operating on ethanol-diesel-biodiesel blends as well as the NO\textsubscript{x}, CO, HC emissions and smoke opacity of the exhaust.

**Objects, apparatus and methodology of the research**

The bench tests were performed on a four-stroke, four-cylinder, direct injection, naturally aspirated diesel engine D-243. The fuel was injected by an in-line fuel injection pump thorough five holes injection nozzles with the initial fuel delivery at 25° CADs before the top dead center (BTDC). The needle valve lifting pressure was set to 19.0±0.5 MPa for all injectors.

The load characteristics of the engine were taken at 1400 min\(^{-1}\) (maximum torque), 1800 and 2200 min\(^{-1}\) (rated speed) when operating alternately on diesel fuel (DF), ethanol-diesel-biodiesel blends 5% ethanol and 95% diesel fuel (B5), 10% ethanol and 90% diesel fuel (B10), 15% ethanol and 85% diesel fuel (B15) and 15% ethanol, 80% diesel fuel and 5% RME (B15E).

The torque of the engine was measured with an electrical AC stand dynamometer. The fuel mass consumption was measured with the AVL fuel balance with an accuracy of ±0.12% and the air mass consumption was measured by using the AVL air metering equipment with an accuracy of ±0.25%.

The cylinder gas pressure diagrams versus the crank angle were recorded at every 0.1 crank angle degree (CAD) by using the AVL indication and data acquisition system. A piezoelectric uncooled transducer GU24D mounted into the first cylinder and connected to the MICROFEM piezoelectric amplifier-signal conditioning along with the AVL crank angle encoder 365C (±0.1°) have been used to record gas pressure for every load-speed setting point with an accuracy of ±0.1 bar.

To determine the start of injection the history of the nozzle-needle-valve lifting was used which was recorded by using the Hall effects position sensor ASMB 470004-1. The needle-valve lifting signals have been transmitted to the Kistler type 5247 amplifier module mounted on the signals conditioning platform Compact 2854 A. The AVL IndiModul 622 was introduced as a multi-channel indicating system for the acquisition and processing of fast crank-angle based cylinder pressure and nozzle-needle-valve lift signals. For the analysis and calculation of the heat release rate the average in-cylinder gas pressure of 100 engine cycles was used.

The autoignition delay was determined as the period in degrees (CAD) between the start of fuel injection (SOI) and the start of combustion (SOC). As the start of injection was taken the point, at which the needle-valve lifts about 5% of its total stroke. As the start of combustion was taken the point, at which the heat release differential curve crosses the zero line and changes its value from minus to plus one. These points were determined with an accuracy ±0.1° of the crank angle degrees.

The amounts of nitric oxide NO (ppm), nitrogen dioxide NO\textsubscript{2} (ppm), carbon monoxide CO (ppm) and total unburned hydrocarbons HC (ppm) in the exhausts were measured with the Testo 350 XL gas analyser. Total emissions of nitrogen oxides NO\textsubscript{x} was determined as a sum of both NO and NO\textsubscript{2} gases. The exhaust opacity (%) was measured with a Bosch RTT 100/RTT 110 opacity-meter with an accuracy of ±0.1°.

**Results and discussion**

The start of fuel injection is important for developing of engine power, economical performance, lower exhaust emissions, and smoke of the exhaust. As Fig. 1a shows, that the start of fuel injection retards for the higher percentage of the ethanol in biofuel blend for all loads at engine speed of 1800 min\(^{-1}\). This can be explained by the fact that adding of the ethanol reduces the fuel density, viscosity and increases the internal leakage in the pump resulting in the later injection of biofuel. It was noted that the addition of rapeseed oil methyl ester to the blend B15 significantly reduced the internal leakage in the blend B15E and advances the start of biofuel injection. Moreover, the presence of RME increases density of biofuel blend and thus increases the pressure wave velocity in the fuel injection line.

Some of the most important factors affecting the autoignition delay, combustion process, maximum cylinder pressure, cylinder pressure gradients and heat release rate are the engine load, speed and the amount of the fuel bound oxygen in the blend. Fig. 1b presents the autoignition delay period as a function of brake mean effective pressure (bmep) at engine speed of 1800 min\(^{-1}\). The analysis of data shows that the autoignition delay increases by 5% (B15) and 12% (B15E) due to the addition of the 15vol% of anhydrous ethanol and 5vol% of RME to diesel fuel compared to normal diesel operating at low load and 1800 min\(^{-1}\) speed. The difference in the autoignition delays between tested blends slightly increased with the increasing engine load. When running at full throttle on blends B15 and B15E, the autoignition delay increased by 18% and 22%, respectively, compared to normal diesel. This means that the combustion process started later for the higher amount of ethanol in the diesel fuel.
Figure 1. Dependency of the start of fuel injection and autoignition delay on engine load (bmep)

Figure 2a presents the maximum cylinder pressure developed by the combustion of various ethanol-diesel-biodiesel blends as a function of brake mean effective pressure (bmep) at engine speed of 1800 min\(^{-1}\). It can be seen that the maximum cylinder pressure decreased by 1–9 % compared to normal diesel due to the use of blends B5-B15E at easy loading conditions. The difference in maximum cylinder pressure developed by the combustion of various blends reduces with the increasing engine load. The difference in \(p_{\text{max}}\) for tested blends decreased by 1-3%, respectively, when operating at full (100%) load. Figure 2b shows the cylinder pressure gradients (\(dp/d\varphi_{\text{max}}\)) for various blends B5-B15E as a function of brake mean effective pressure (bmep) developed at 1800 min\(^{-1}\) speed. The maximum cylinder pressure gradients developed when running on blends B5-B15E were lower if compared to those of normal diesel operating at light loads. For this reason, the maximum pressure gradients were noticeably lower for all ethanol-diesel-biodiesel blends. Whereas, the maximum cylinder pressure gradients for all tested blends increased more intensively with engine load, so that their values became similar to that of normal diesel, despite the longer autoignition delay of the tested biofuel blends.

Figure 2. Dependency the in-cylinder maximum pressure (\(p_{\text{max}}\)) and maximum cylinder pressure gradient (\((dp/d\varphi_{\text{max}}))\)) on engine load (bmep)

The combustion changes have influence on the engine brake specific fuel consumption. As Fig.3a shows, the lowest brake specific fuel consumption (bsfc) was received by using blend B5 at low load and 1800 min\(^{-1}\) speed. When operating on biofuel blends B5-B15E, the brake specific fuel consumption of increased by 3.5–8.9 %, respectively, against normal diesel running at full (100%) load. The higher brake specific fuel consumption of biodiesel was obtained because of 1.9% to 6.7% lower net heating value of the fuel blends.

Figure 3. Dependency of the brake specific fuel consumption (bsfc) and brake thermal efficiency (\(\eta_{\text{b}}\)) on engine load (bmep)
It can be seen (Fig. 3b) that the brake thermal efficiency for the tested blends B5-B15E was 1.5–4.7% higher compared to normal diesel operating at light load and 1800 min⁻¹ speed. However, the brake thermal efficiency of the engine increased less intensively with load, so that when operating at full (100%) load it sustained at the levels 1% to 3.0% lower compared to the normal diesel fuel case.

Fig. 4a shows the maximum nitrogen oxide emissions as a function of brake mean effective pressure (bmepr) for all biofuels blends used at 1800 min⁻¹ speed. It is clear that the maximum NOₓ emissions produced by biodiesel were much lower compared to normal diesel operation at full load.

When running on biofuel blends B5, B10, B15 and B15E the maximum emissions of nitrogen oxides NOₓ were decrease by 6.2%, 16.4%, 21% and 17%, respectively. The decrease in total nitrogen oxides can be explained by the lower gas pressure and temperature in the cylinder as the combustion and heat release processes were moved towards a bigger cylinder volume in the expansion stroke.

It can be seen in Fig.4b that the carbon monoxide CO emissions produced by the combustion of blends B5, B10, B15 and B15E were 10.1%, 4.3%, 23.8%, and 56.7% higher than normal (457 ppm) diesel operating at light load. When the engine load was increased, the difference in the CO emissions slightly decreased, so that the CO emissions from biodiesel were 10.5% (B15) to 12.6% (B15E) higher at full load. The increase of carbon monoxide CO emissions can be attributed to the lower cetane number and the longer autoignition delay of biodiesel.

The analysis of Fig. 5a shows that unburned hydrocarbons HC emissions were lower throughout the entire load range when operating on blends B15 and B15E. When running on blends B15 and B15E the emissions of unburned hydrocarbons HC were 90.4% and 14.9% lower compared to normal diesel operating at medium load, whereas, in case of using less oxygenated blends B5 and B10, the HC emission were 17.9 % and 20.1 % higher, respectively. Analysis of the data shows Fig. 5b that the biggest opacity of the exhaust (by 15%) produced the combustion of blend B5 at full load. Whereas the use of blend B10 suggested the smoke opacity about 9.0% lower than a strait diesel running at full load.

**Conclusion**

When running on blends B15 and B15E the autoignition delay was 18% and 22% longer, respectively, compared to the normal diesel fuel used at full load and 1800 min⁻¹ speed.

The maximum cylinder pressure decreased by 1–3% for biodiesel blends B5, B10, B15, and B15E compared to normal diesel operating at full load and 1800 min⁻¹ speed.

The minimum brake specific fuel consumption increased by 3.5%, 5.3%, 8.9%, and 7.6%, respectively, when operating on biofuel blends B5, B10, B15 and B15E compared to normal diesel running at 1800 min⁻¹ speed and full
load. The maximum brake thermal efficiency sustained at the levels 1% to 3.0% lower compared to normal diesel operating at full (100%) load.

The total NO\textsubscript{x} emissions from combustion of blends B5, B10, B15 and B15E were 7.2%, 10.3%, 12.8% and 11.1% lower and the CO emissions 10.5%, 13%, 20.1%, and 37% higher, respectively. Changes in the HC emissions were not conclusive and smoke opacity of the exhaust was about 9.0% lower when operating on blend B10 compared to normal diesel running at moderate load and 1800 min\textsuperscript{-1} speed.

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Influence of Specific Degradation Liquid Contaminants of Agricultural Production on Shear Impact Strength of Adhesive Bond

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Abstract

A complexity and a sustainability of systems in the agriculture are key factors, namely in an integration with keeping an ability to secure aliment and connected food stuff production. In the paper there are stated results of a research focused on using an adhesive bonding technology as a possible way for bonding or for securing various accessory materials distinguished for increased wear resistance. Nowadays, a method of a brazing is used. However, this method is expensive compared with the adhesive bonding technology. A research in this area of connecting tools is unfathomed for the moment. An application of this solution requires coping with the adhesive bonding technology in the area of rigid and sufficiently tenacious bond which is resistant to liquid contaminants occurring in the application area.

On the base of carried out experiments it is possible to say that the resultant shear impact strength of the adhesive bond decreases owing to exerting of the liquid contaminants. The measure of the strength decrease depends on specific conditions of the environment. The significant decrease of the shear impact strength occurred namely owing to the influence of the mineral fertilizer. Within various tested adhesives the average decrease was 26.17%. The considerable decrease occurred at two-component epoxy adhesives and at a polyester adhesive. The minimum decrease of the shear impact strength was set at the adhesive Metyl-methacrylat.

Introduction

A complexity and a sustainability of systems in the agriculture are key factors, namely in an integration with keeping an ability to secure aliment and connected food stuff production. One of means reaching the sustainability in the sphere of the food production can be a conventional soil processing. Machines, equipments and their partial segments working under conditions of the agriculture are exposed to an intensive abrasive wear, namely in the sphere of the soil processing. Regarding the wear conditions and the process intensity are an integral part of a service life and reliability not only of tools, but also the whole systems (MÜLLER, CHOTĚBORSKÝ 2012).

Currently many experts (NATSIS et al. 1999; NATSIS et al. 2008; HORVAT et al., 2008; BAYHAN 2005; OWSIAK 1997; VALÁŠEK 2011) deal with the problems of increasing the service life of segments processing the soil.

The research aim of various working groups can be defined as following: finding suitable materials and methods for the production of optimum tools whose mechanical properties would extend the tools service life and they would decrease the energetic consumption of the soil processing owing to the lower resistance MÜLLER, CHOTĚBORSKÝ 2012; MÜLLER, HRABĚ, 2013).

The practical experience e.g. at machine tools clearly shows a trend of exchangeable cutting tips that means a bimetallic solution. This trend can be gradually seen at the tools processing the soil or wood (fig. 1).

Figure 1. Example of adhesive bonding of cutting tip of tool for machining wood

The possible solution is a creation of bimetallic tools on one hand and various additional materials on the other hand. Sintered carbides are the most widespread cutting material these days. Important producers of exchangeable parts of the soil processing machines increase the wear resistance of their tools due to the e. g. the tungsten carbide (MÜLLER, CHOTĚBORSKÝ 2012). Bonding methods are the defined problem of various materials. Currently a method of a brazing is used. However, this method is expensive and it cannot be applied in all cases. An adhesive bonding is the general bonding technology which enables to bond heterogeneous materials in effective way. A research in this area of bonding tools is unfathomed for the moment namely owing to a high dynamic potential put on the product. The problematic area is namely liquid contaminants occurring during the soil processing and contaminants exerting e.g. on fuel systems (MÜLLER 2013; MÜLLER, VALÁŠEK 2012; KUBÍN, PEXA 2010; PEXA at al. 2013; PEXA, KUBÍN 2012).

Analysing the problem following key problems can be set:

- A sufficient strength of the adhesive bond,
A resistance to a dynamic behaviour, that means to impacts,
A resistance to increased temperature,
A resistance to contaminants occurring in a given area.

The paper presents the results of the research focused on using the adhesive bonding technology as the possible way for bonding or securing various accessory materials distinguished for increased wear resistance. The tool wear can be decreased not only by the material distinguished for increased wear resistance but also by the accessory equipment which solves given problem in the effective way. Then it is possible to speak about the constructional solution which requires to find suitable bonding technology. The disadvantage of the adhesive bonding technology is namely low impact strength. This fact is essential in the application in the sphere of exchangeable wear parts processing the soil. The integral part of the research work is the evaluation of not only the own impact strength, but also the temperature affecting the adhesive.

The aim of the research is an evaluation of a possibility to apply the adhesive bonding technology in the area of the connecting wear resistant parts of tools processing the soil. Nowadays, a method of the brazing is used for connecting wear resistant materials (sintered carbides) and steel. The research was carried out in research laboratories of CULS.

The application of this solution requires knowing the adhesive bonding technology in the sphere of rigid and sufficiently tenacious bond which is resistant to the liquid contaminants.

Material and methods

The shear impact strength of the adhesive bonds simulates conditions of expected loading at the practical application that means during processing the soil in the effective way. Own course of the laboratory test is described by the standard CSN EN ISO 965 (2001). However, a suitable constructional design of the tested equipment in not defined.

The suggestion and design of the equipment for the evaluation of the shear impact strength of adhesive bonds were the subject of the utility pattern no. CZ 23585 U1 (2012). The subject of the utility pattern is the tester for the evaluation of the shear impact strength of adhesive bonds. The equipment is composed of two parts, the impact hammer and the equipment part for fixing the tested sample. The equipment for the shear impact strength of adhesive bonds is distinguished for simplicity of the constructional design, the shape and the geometry. The constructional design enables to use principles of a method for testing the impact strength according to Charpy. A rigidity of the equipment construction for fixing the tested samples made from one piece of steel secures fixing under the same conditions and connected reproducibility of following tests. The impact hammer is suspended on a lead rod of the original Charpy hammer. The constructional design of the impact hammer enables the testing variability owing to the exchangeable crashing plate provided that the conditions about the minimum width against the impact area of the tested sample given in the standard are fulfilled.

The shear impact strength was tested at adhesive bonds made from steel/steel, bottom sizes of the sample 45 x 25 x 20 mm, upper sizes 25 x 25 x 10 mm.

Standard CSN EN ISO 965 (2001) states mainly the shape and sizes of the tested samples. Ahead of bonding the surface of bonded specimens (steel S235J0) was blasted using the Al₂O₃ of F80 grain size. Using the profilograph Surftest 301 following values were determined: Ra 1.9 ± 0.1 μm, Rz 12.5 ± 1.2 μm.

A constant thickness of the adhesive layer was secured by means of a weight of 720 g. The real thickness of the adhesive layer 71.13 ± 19.10 μm was found out by means of a picture analysis of the adhesive bond cut (fig. 2). Adhesive bonds were left under the laboratory conditions (temperature 22 ± 2 °C) for hardening for 48 hours.

The following list presents the identification of tested adhesives which is used in text for better clear arrangement:

- Two-component epoxy adhesive Loctite Nordbak 7256 (LN7256),
- Two-component epoxy adhesive Lepox 1200 (L1200),
- Two-component epoxy adhesive 3-TON Epoxy adhesive 30 min (3TON),
- Metyl-methacrylat Novatit (N-MET),
- Polyester MTB (MTB).

The adhesive bonds were placed into the degradation environment (rain water, solution of water and halite, machine oil, fertilizer Cererit) after reaching full hardening. The tested samples were exposed to the degradation environment for 60 days. Each cycle (60 days) was terminated by a destructive testing on the Charpy hammer and by defining the failure type.
Results and discussion

It was tested a few types and sorts of adhesives. Adhesives behaved differently during testing. Fig. 3 shows the schematic presentation of the impact shear strength results of adhesive bonds created by means of ANOVA by the lowest squares methods. From the results presented in the fig. 3 the results of single adhesive and the influence of the liquid contaminants compared with the laboratory environment are obvious. Tukey’s HSD test was used for the statistical comparison of mean values. In the table 1, there are presented single means in the statistically homogeneous groups.

An essential conclusion results from the analysis that there is not the statistical dependence in the shear impact strength of the adhesive bonds among single adhesives nor environments. The adhesives showed significant strength differences. However, from the fig. 3 a similar trend of the two-component epoxy adhesives and the polyester adhesive in various environments is obvious. The adhesive methyl-methacrylat N-met behaved differently. This adhesive showed statistically the same behaviour under the laboratory conditions, in the water, in the solution of the water and halite and in the fertilizer. The oil bath exerted in positive way on increasing the shear impact strength. Increased shear impact strength of the adhesive bond contaminated by the oil was found out at the two-component epoxy adhesive 3TON too. However, this value was lower than in the laboratory environment.

The failure areas of destroyed adhesive bonds placed in the degradation environments showed various types of the failure. In the first phase they showed identically the cohesive failure area, prospectively the adhesive cohesive failure.
Table 1. Statistical comparison of mean values – Tukey’s HSD test

<table>
<thead>
<tr>
<th>Adhesive</th>
<th>Environment</th>
<th>Arithmetical mean (J.m²)</th>
<th>Agreement</th>
</tr>
</thead>
<tbody>
<tr>
<td>L1200</td>
<td>Cererit</td>
<td>5280</td>
<td>*</td>
</tr>
<tr>
<td>MTB</td>
<td>Cererit</td>
<td>5440</td>
<td>*</td>
</tr>
<tr>
<td>LN7256</td>
<td>Cererit</td>
<td>6080</td>
<td>*</td>
</tr>
<tr>
<td>N-MET</td>
<td>Water</td>
<td>6560</td>
<td>*</td>
</tr>
<tr>
<td>N-MET</td>
<td>Water + halite</td>
<td>6640</td>
<td>*</td>
</tr>
<tr>
<td>L1200</td>
<td>Water + halite</td>
<td>6720</td>
<td>*</td>
</tr>
<tr>
<td>N-MET</td>
<td>Cererit</td>
<td>6800</td>
<td>*</td>
</tr>
<tr>
<td>L1200</td>
<td>Oil</td>
<td>6840</td>
<td>*</td>
</tr>
<tr>
<td>L1200</td>
<td>Water</td>
<td>6880</td>
<td>*</td>
</tr>
<tr>
<td>L1200</td>
<td>Laboratory</td>
<td>6920</td>
<td>*</td>
</tr>
<tr>
<td>3TON</td>
<td>Cererit</td>
<td>6920</td>
<td>*</td>
</tr>
<tr>
<td>N-MET</td>
<td>Laboratory</td>
<td>6960</td>
<td>*</td>
</tr>
<tr>
<td>LN7256</td>
<td>Water + halite</td>
<td>7120</td>
<td>*</td>
</tr>
<tr>
<td>MTB</td>
<td>Water</td>
<td>7120</td>
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</tr>
<tr>
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</tr>
<tr>
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<td>*</td>
</tr>
<tr>
<td>MTB</td>
<td>Water + halite</td>
<td>7520</td>
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</tr>
<tr>
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<td>Oil</td>
<td>7640</td>
<td>*</td>
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<td>Laboratory</td>
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A significant reason having the influence on the adhesive bonds strength decreasing is the diffuse seepage of the degradation medium into the adhesive bond. The functional area that means the overlapping area was constantly lessened by this and so it came to the adhesive bonds strength decreasing. So it came not only to the decreasing of the cohesive strength by the humidity and chemical stuffs diffusion into the adhesive bonds but also to decreasing of the adhesive adhesion.

From the fig. 4 the cohesive failure area and the diffuse seepage of liquid contaminant (the solution of water and halite) are visible. Fig. 4 also presents a considerable corrosion of the adhesive bonded material (steel S235J0). The fig. 5 shows a huge diffuse seepage of the oil in the area of the bond adhesive bonded by the adhesive 3TON. The failure area of the adhesive MTB placed in the fertilizer Cererit was of the cohesive type with the typical structure (fig. 6) also after 60 days. Liquid contaminants behaved in the following way:

- The diffuse seepage was found out at all contaminants and adhesives.
- Significant damage of cohesive bonds was caused by the contaminants oil and mineral fertilizer Cererit. At the oil it came to destroying of the adhesive structure but the decrease of the shear impact strength was not so considerable.
- Considerable decrease of the shear impact strength was found out at the fertilizer.
- Water and the solution of water and halite exerted on the shear impact strength surprisingly in similar way. Increased effect of the halite was not proved.

Experiments results confirm the statements of Müller (2013) and Crocombe (1997) about the distribution of the humidity into the layer of the adhesive. Also the negative effects of liquid contaminants are confirmed.
Conclusions

On the base of the evaluation of carried out experiments it can be said that resultant shear impact strength of the adhesive bond decreases owing to the influence of the liquid contaminants exerting. The measure of the decrease depends on the specific conditions of the environment.

These conclusions were set from the experiments:

- Considerable decrease of the shear impact strength occurred namely at exerting of the mineral fertilizer. Within various tested adhesives the average fall was 26.17%. The significant fall was recorded at the two-component epoxy adhesives and the polyester adhesive. The minimum decrease of the shear impact strength was set at the adhesive methyl-methacrylat.

- The change of the failure area from the cohesive to the adhesive-cohesive one was not primarily caused by the degradation process. From the results it is visible that the corrosion of the adhesive bonded materials (adherents) is not in most cases entirely explicit agent having the influence on the adhesive bond strength. At the adhesive bonds where the corrosive products occurred in the layer of the adhesive it did not come to more considerable accelerated process of the shear impact strength decrease. The strength decrease showed a linear trend. The example is the water with halite.

- Liquid contaminants diffuse into the layer of the adhesive and they reduce the functional area of the overlapping acting on the transfer of the loading force.
Laboratory tests showed increased resistance of methyl-methacrylat adhesive. The decrease of the shear impact strength ranged in the interval 2.3–5.8%. As the only adhesive it increases its shear impact strength of 23.5% in the oil bath. When evaluating the failure area the change of the colour occurred only.

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Concepts and Profitability For utilisation of Fish-Industry Side-Stream

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Abstract

This study evaluates the possibility of increasing the oil and protein utilisation of the fish-processing side-streams and also of applying these side-streams for the co-generation of biogas and fertilisers on a farm. The study introduces three concepts: 1) processing of the fish side-stream at a farm biogas plant; 2) the fish protein concentrate (FPC) process, wherein oil is thermally extracted and protein concentrate and meal are used as a feed; and 3) a two-stage process for producing high-quality oil and protein-rich hydrolysate and meal. The possibility of utilising meal at a farm biogas plant is also considered, for concepts 2 and 3. Production costs and revenues associated with the processes are evaluated, and the uncertainty of the process parameters is analysed. The results show that the fish side-stream examined here is too expensive for direct utilisation at a farm biogas plant, but with a lower-cost side-stream the process could be profitable. The processes producing concentrate and hydrolysate are both profitable; in addition, the hydrolysate concept, with value-added more expensive products, shows advantages over the concentrate concept.

Introduction

The utilisation and refining of process side-streams are important factors for sustainable, economically viable development of the seafood industry. The seafood industry produces many kinds of side-streams, which are currently wasted or used as low-value products (Rustad et al., 2011). In addition, optimisation of the fish catch is needed because fish resources are limited. Fish side-streams provide a good source of nutrients like high-quality marine oils and proteins, and they can be used for many purposes, including production of novel and value-added products for the nutraceutical, pharmaceutical, and fine chemical industries. The quantities of these side-streams can be significant. For example, the volume of the fish-processing side-stream from Norwegian salmon aquaculture is approx. 350 000 t per year (Olafsen et al., 2013), and there are 70000 t of lipids and 52000 t of proteins available in that side-stream.

For full utilisation of this side-stream’s potential, a techno-economically feasible and sustainable zero-waste process is needed. The aim is to produce high-value products such as biomaterials, ingredients, and additives for food and skin-care formulations and finally utilise the remaining residue for co-generation of energy and soil fertilisers.

This study presents three concepts for utilisation of the fish industry side-streams further processing of the residue on a farm for renewable energy and fertiliser production. These concepts are 1) energy and fertilisers production in a biogas plant from the side-stream, no further processing after fish filleting 2) fish protein concentrate (FPC) and fish meal production wherein oil is thermally extracted from the side-stream and residue is used as feed or feedstock for concept 1; and 3) production of high-quality oil and protein-rich hydrolysate, at a two-stage process and utilisation of residue as feed or feedstock for concept 1.

The study focuses on techno-economic evaluation of the processes described. Mass and energy balances are estimated. Usage of raw material, utilities, and need of chemicals are evaluated, and the variable production costs are estimated. Also, estimates of operating costs and investment costs are calculated. The uncertainty in early stage process design is also taken into account.

Approach

The studied processes use salmon filleting side-stream (dry matter (DM) around 43%); skeletons/backbones as raw material, end products, depending on the use processing technology, are fish oil, fish meal, fish protein concentrate, fish protein hydrolysate (FPH), energy, and fertilisers. The three concepts proposed are described next.

Concept 1. Fish side-stream has a high energy value and relatively high dry matter content and also high concentration of nitrogen and phosphorous. Therefore co-digestion of cattle manure and fish side-stream is considered as improvement for biogas plant efficiency as well for digestate quality (Venslauskis et al. 2013b). In the anaerobic digestion, the raw material is converted into biogas and digestate. Biogas, a mixture of mainly methane and carbon dioxide, is used for co-generation of heat and power (CHP). The digestate is nutrient-rich and can be used as fertiliser (see Figure 1).

Concept 2. The salmon filleting side-stream is minced to produce homogenous feed for the process. Thermal extraction is used to separate the oil from the raw material, after which the individual phases are separated, with, for example, atricanter. The separated phases are oil, protein-rich stick water and meal. Meal is dried, and the aqueous phase – e.g., stick water is evaporated to 50% concentration. The fish protein concentrate process is common process today (Kristinsson et al., 2007). Products can be used as animal feed, or further processed to create electricity and fertilisers. (see Figure 2).

Concept 3. The two-stage process is a novel process and introduces enzymatic treatment for the defatted fraction. The process differs from the FPC process in its use of gentler thermal extraction, to obtain premium oil. Thermal extraction also minimises the amount of oil in the remaining enzymatic process. From thermal extraction, the defatted
fraction continues to enzymatic treatment. Enzymes are inactivated by heating after the enzymatic hydrolysis. The phase separator is applied to separate the oil, solid, and aqueous phases. Solids (e.g., meal) are dried, and the aqueous phase (e.g., protein hydrolysate) is evaporated to 50% concentration. With the gentle processing of the fish side-stream, more value-added products are obtained also for human consumption (Thorkelsson et al., 2009; Slizyte et al., 2005) (see Figure 3).

Figure 1. The proposed concept for co-generation of energy and fertilisers from fish-processing residue, concept 1

Figure 2. The proposed concept for the fish protein concentrate process; concept 2

Figure 3. The proposed concept for the two-stage process, concept 3

Spreadsheet models were built for biogas-plant, fish protein concentrate, and two-stage process, to generate mass and energy balances. Production costs and revenues were calculated to obtain profitability of the concepts. The costs are determined in line with the assumptions made in the calculations. The data on which the assumptions were based came from responses to a questionnaire, from further conversations with partners in the EU project APROPOS, and from the literature (e.g., Shahidi, 2007).
The fixed costs include labour, plant overhead costs, maintenance, miscellaneous costs, and capital depreciation. Variable costs include raw-material costs; chemical costs; and utilities, such as water, electricity, and steam. The concepts are zero-waste processes, so no waste treatment is needed.

The profitability of the various concepts is evaluated in terms of return on investment (ROI), calculated as the benefit of the investment divided by the cost of investment. This is expressed thus:

\[ ROI = \frac{\text{Annual net profit}}{\text{Investment costs}}. \]  

Early stages in process design include huge amounts of uncertainties. To address this matter, Monte Carlo simulations (Rubinstein, 1981) are employed. Instead of fixed values for process parameters and prices, a distribution of possible values is introduced as input. By means of multiple simulation runs, probability distributions for the output factors, such as total costs, are obtained. In addition, sensitivity analysis for various factors is conducted simultaneously.

**Assumptions and input parameters**

In concept 1, the fish filleting side-stream is digested with cattle manure in the manner suggested by Navickas et al. (2013a and b). The operation time of the biogas plant is 8000 h/year, and the fish side-stream and cattle manure are mixed in a 1:5 ratio. The same side-stream capacity is assumed for all concepts (11500 t/year), yielding 69 000 t/year of biogas produced. Table 1 summaries the input parameters for concepts 2 and 3; it presents the mean values in the simulations, summarised in Table 1. Revenue is gained from energy in the form of electricity and heat and also from fertiliser. The estimates of electricity prices assume a subsidised price of €0.095/kWh, the heat price estimate is €0.04/kWh, and the fertiliser price used is €0–5.7/t (UK Environment Agency information, 2009).

Table 1. **Input parameters included in sensitivity analysis, concept 1**

<table>
<thead>
<tr>
<th>Feedstock: manure and fish side-stream</th>
<th>Mean</th>
<th>Min. (&gt;5%)</th>
<th>Max. (&lt;95%)</th>
<th>Distr. type</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHP electrical efficiency (%))</td>
<td>37 %</td>
<td>34 %</td>
<td>41 %</td>
<td>Normal</td>
</tr>
<tr>
<td>Production of biogas from feedstock (m³/t)</td>
<td>88</td>
<td>79</td>
<td>97</td>
<td>Normal</td>
</tr>
<tr>
<td>Investment cost (k EUR)</td>
<td>5 974</td>
<td>4 233</td>
<td>7 981</td>
<td>Normal</td>
</tr>
<tr>
<td>Lifetime (years)</td>
<td>10</td>
<td>8</td>
<td>12</td>
<td>Normal</td>
</tr>
<tr>
<td>Fish side-stream price (EUR/t)</td>
<td>106</td>
<td>85</td>
<td>127</td>
<td>Normal</td>
</tr>
<tr>
<td>Electricity price (EUR/kWh)</td>
<td>0.095</td>
<td>0.076</td>
<td>0.114</td>
<td>Normal</td>
</tr>
<tr>
<td>Heat price (EUR/kWh)</td>
<td>0.025</td>
<td>0.020</td>
<td>0.030</td>
<td>Normal</td>
</tr>
<tr>
<td>Digestate price (EUR/t)</td>
<td>2.875</td>
<td>0.000</td>
<td>5.748</td>
<td>Normal</td>
</tr>
</tbody>
</table>

Both processes under concepts 2 and 3 (fish protein concentrate process and two-stage process) operate in one shift, giving operation time 2890 hours per year. The side-stream capacity is 11 500 t/year as mentioned above, yielding 4000 kg/h. The estimates of investment costs are based on the reference plant for the concept 2 (€7.47M updated for 2011 prices). Concept 3 is estimated as costing 30% more, as it includes more process units and food-grade material is produced. Table 3 summarises the input parameters for concepts 2 and 3; it presents the mean values in the simulations, the distribution type, and the 5% and 95% percentiles. Phase separation here is based on ‘dividing factors’, which refer to the amount of the component (oil, protein, ash, or water) separated out into the selected fraction. The dividing factors shown in Table 2 are based on laboratory experiments; however, the factors’ values involve uncertainty so have undergone uncertainty evaluation (5% and 95% percentiles account for ±15% of the value).
Table 3. Input parameters with value distributions for the fish protein concentrate and two-stage process models

<table>
<thead>
<tr>
<th>Input parameters</th>
<th>Mean</th>
<th>Min. (&gt;5%)</th>
<th>Max. (&lt;95%)</th>
<th>Distr. type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production capacity</td>
<td>4 000</td>
<td>3 100</td>
<td>4 900</td>
<td>Uniform</td>
</tr>
<tr>
<td>Composition</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>oil (%)</td>
<td>23 %</td>
<td>21 %</td>
<td>26 %</td>
<td>Normal</td>
</tr>
<tr>
<td>protein (%)</td>
<td>16 %</td>
<td>14 %</td>
<td>17 %</td>
<td>Normal</td>
</tr>
<tr>
<td>ash (%)</td>
<td>4 %</td>
<td>3 %</td>
<td>4 %</td>
<td>Normal</td>
</tr>
<tr>
<td>Enzyme charge (g/kg)</td>
<td>1.0</td>
<td>0.5</td>
<td>1.5</td>
<td>Normal</td>
</tr>
<tr>
<td>Fish side-stream (EUR / t wet)</td>
<td>106</td>
<td>99</td>
<td>113</td>
<td>Triangle</td>
</tr>
<tr>
<td>Formic acid (FA) (EUR/t, 80% FA)</td>
<td>933</td>
<td>926</td>
<td>940</td>
<td>Triangle</td>
</tr>
<tr>
<td>Enzyme (EUR/kg)</td>
<td>20</td>
<td>13</td>
<td>27</td>
<td>Triangle</td>
</tr>
<tr>
<td>Steam (EUR/t)</td>
<td>21</td>
<td>19</td>
<td>22</td>
<td>Triangle</td>
</tr>
<tr>
<td>Electricity (EUR/kWh)</td>
<td>0.10</td>
<td>0.09</td>
<td>0.11</td>
<td>Triangle</td>
</tr>
<tr>
<td>Investment cost, FPC (k EUR)</td>
<td>7 225</td>
<td>5 225</td>
<td>9 381</td>
<td>Normal</td>
</tr>
<tr>
<td>Investment, FPH (k EUR)</td>
<td>9 392</td>
<td>6 792</td>
<td>12 196</td>
<td>Normal</td>
</tr>
<tr>
<td>Lifetime (years)</td>
<td>15</td>
<td>10</td>
<td>20</td>
<td>Normal</td>
</tr>
<tr>
<td>Rate of interest (%)</td>
<td>7 %</td>
<td>5 %</td>
<td>9 %</td>
<td>Normal</td>
</tr>
<tr>
<td>Labour (persons)</td>
<td>3</td>
<td>2</td>
<td>4</td>
<td>Discrete</td>
</tr>
<tr>
<td>Average salary (EUR/year)</td>
<td></td>
<td></td>
<td>60 000</td>
<td></td>
</tr>
<tr>
<td>Overheads (% of labour costs)</td>
<td>37 %</td>
<td>25 %</td>
<td>50 %</td>
<td>Normal</td>
</tr>
<tr>
<td>Maintenance and repairs (% of investment)</td>
<td>2.5 %</td>
<td>1.5 %</td>
<td>3.5 %</td>
<td>Normal</td>
</tr>
<tr>
<td>Other (% of investment)</td>
<td>1.0 %</td>
<td>0.5 %</td>
<td>1.5 %</td>
<td>Normal</td>
</tr>
<tr>
<td>Fish oil 1 (EUR / dry t)</td>
<td>1 210</td>
<td>1 127</td>
<td>1 293</td>
<td>Triangle</td>
</tr>
<tr>
<td>Fish oil 2 (EUR / dry t)</td>
<td>1 100</td>
<td>1 025</td>
<td>1 175</td>
<td>Triangle</td>
</tr>
<tr>
<td>Fish meal (EUR / dry t)</td>
<td>1 212</td>
<td>1 069</td>
<td>1 354</td>
<td>Triangle</td>
</tr>
<tr>
<td>Fish protein hydrolysate (EUR / dry t)</td>
<td>3 500</td>
<td>2 542</td>
<td>4 457</td>
<td>Triangle</td>
</tr>
<tr>
<td>Fish protein concentrate (EUR / dry t)</td>
<td>800</td>
<td>581</td>
<td>1 019</td>
<td>Triangle</td>
</tr>
</tbody>
</table>

Results and discussion

The fixed-point assessment shows concepts 2 and 3 as profitable; with annual profit for FPC being €2.15 million and the ROI 31% and the corresponding figures for the two-stage process being €4.74 million and 52%. In contrast, concept 1 is unprofitable; the annual profit is €1.15 million and ROI is 20% to the negative. Revenues with concepts 2 and 3 come from fish oils, fish protein concentrate or hydrolysate, and fish meal, and those for concept 1 are from energy and fertiliser. Raw materials and chemicals represent the largest proportion of production costs: 42–46%, depending on the concept applied. The share of capital depreciation is high also, 29–31%, with all of the concepts. Figure 4 summarises the results for fixed-point assessment. Both production costs and revenues are higher for the two-stage process than for the FPC process. The higher revenues are a result of the higher selling price of protein hydrolysate compared to protein concentrate. Also, revenue from the oil fraction is slightly higher in the two-stage process.
Uncertainty in the calculations was addressed by means of Monte Carlo simulation. Figure 5 summaries the production cost, revenues, and profit intervals with the input distributions used. When uncertainty is taken into account, both FPC and the two-stage process are always profitable, while concept 1 is always unprofitable.

Figure 5. Summary box plots of the annual production costs, revenues, and profits for all three concepts

Figures 6 and 7 show the change in profit across the most sensitive input variables. The steeper the line in the graph is, the greater the impact of the input on the profit. For concepts 2 and 3, the process becomes more economical as plant size grows – this is unsurprising, because capital costs depend on capacity and it is quite common that larger plant is more economic. Product prices are also crucial with these concepts. For concept 2, oil yield is a significant factor. Both the fish protein concentrate and the two-stage process seem very profitable: both processes have reasonably high product prices, with the hydrolysate prices being a particularly strong reason for the two-stage process’s excellent profitability. Another benefit of the processes is the location assumed, next to a fishery, which results in negligible delivery costs for raw material.

Figure 6. Change in profit across the range of input values for concept 2

For the concept 1, the fish side-stream accounts for 46% of total costs. This is a major reason for the concept not being profitable. In view of this, further processing of the meal fraction from concepts 2 or 3 via anaerobic digestion was ruled out, since these fractions have even higher prices than the fish side-stream. As seafood-based raw materials are highly perishable, it might be possible as an alternative to find another side-stream that do not reach the requirements of concepts 2 and 3, so cost less, but are still valuable for anaerobic digestion. Price near zero (€6.3/t) for the fish side-stream did make concept 1 profitable in the fixed-point assessment. In uncertainty analyses for the concept 1 that were carried out with zero price for the fish side-stream, 1.2% ROI was obtained, making this concept slightly profitable. Figure 9 shows the change in profit across the range of the most significant input variables. Changes in electricity and digestate prices, along with the capital investment, are the most significant factors affecting the profitability of concept. Higher-price electricity and a smaller investment in capital would make the process more profitable. It is worth noting, in addition, that biogas plants in Europe are commonly given an investment grant or subsidised in other ways. With concept 1, the plant location was not specified, and the maintenance and other fixed costs were kept the same as under
the other two concepts. These numbers should be investigated further, the locations should be fixed, and location-based investment grants or electricity subsidies should be factored in, to yield a more precise concept analysis. However, it can be noted already that the fishside-stream has an advantage over digestion of manure alone, because of the higher biogas yield and more nutrient-rich digestate. The delivery costs and price of the fish side-stream are factors affecting the profitability relative to digestion of pure cattle manure.

Figure 7. Change in profit across the range of input values for concept 3

Figure 8. Change in profit across the range of input values for concept 1, €0/t being the price of the fish side-stream

Conclusion

Estimates were calculated for the production costs and feasibility of the three concepts for processing of fish side-stream. The uncertainties of the early-stage concept design were addressed by means of sensitivity analysis using Monte Carlo simulations. The main results can be summarised thus:

- The fish protein concentrate process (concept 2), and two-stage process (concept 3) were profitable, while biogas production (concept 1) was found to be unprofitable with used assumptions. If the fish side-stream price is near zero, concept 1 becomes profitable.

- In all concepts, feedstock (i.e., the fish side-stream) and capital depreciation are the main contributors to the costs.

- The enzymatic two-stage process (concept 3) displays an advantage over the fish protein concentrate process (concept 2), mainly because of higher product prices.

- Utilising meal as feedstock for biogas production is unprofitable, since the price of meal is higher than the price of the fish side-stream.

- For co-digestion of cattle manure and fish side-stream, the fish side-stream should be less valued side-stream than the studied one.

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References


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Added Energy Value from Application of Fish Industry Co-Streams

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Abstract

Added energy value from application of fish industry co-streams for biogas production and use of substrates for soil fertilising is discussed in the paper. The analysis of added value of fish co-streams was done by comparing two different scenarios. Scenario 1 represents the system of the fertilisation of arable land intended for summer barley growing and Scenario 2 – arable land is fertilised with a digestate of mixture of fish co-streams and cattle manure after anaerobic digestion. The farm system corresponding 600 milking cows producing 12000 t/year of manure having 600 ha of cultivated land has been used and the mass of fish waste is estimated to be 2400 t per year. The energetic evaluation has been performed including direct and indirect energy inputs for all technological operations and processes. Results of the study suggest that fish waste used for biogas production and soil fertilization generates additional energy value for the farm.

Introduction

The world is concerned about the use of natural resources, and deployment of sustainable practices and goals. Greater attention should be given to sustainable agriculture, fisheries and aquaculture, better nutrition and solving water scarcity and food waste problems. This would ensure the efficient use of resources based on production, water conservation, and waste reduction and recycling (Ending poverty..., 2013).

The production of fish products for human consumption on an industrial level generates a significant quantity of co-streams, which is considered as a waste or/and is used for low cost products. The generated co-products containing fish protein and oil currently are used mainly as feed for animals, however such co-streams have components upgradable into valuable products. The final products after several processing stages of co-streams still are rich in oil, protein, amino acids and vitamins.

It is estimated, that 50–75% of the fish ends up as co-stream in the seafood industry (Guerard et al., 2005; Shahidi 1994). Fish processing co-streams are produced in considerable quantities (13 million metric tons) at European level (Navickas et al., 2013a). The situation in Norway shows that approx. 68 % fish processing co-streams are used for fish meal and silage production and ~12% for oil and hydrolysates (Olafsen et al., 2013). The scientists are looking for the application of enzymatic technologies for recovery of high quality valuable fish oil and proteins from fish co-streams (Slizyte et al., 2005a; Slizyte et al., 2005b). The remaining products after the recovery of valuable products from fish co-streams could be used for biogas production (Navickas et al., 2013a) and biofertilizer generation (Navickas et al., 2012). Animal by-products utilisation and biogas generation support the 20 % target of European Union (EU 27) for the contribution of renewable sources from final energy consumption by 2010 (Renewable Energy…, 2008). The use of biomass for energy generation reduces the greenhouse gas emissions compared to the use of fossil fuels (Navickas et al., 2011b).

Fish co-streams contain high concentration of nitrogen (N) and phosphorus (P) (Lemarié et al., 1998). The co-digestion of fish co-streams with cattle manure could improve an energy efficiency of biogas plant and fertilisation quality of final digestate. The digestate could be used as an organic fertiliser for the fields of the farm. The composition and ratio of mixing fish co-streams with cattle manure has to be adapted to the plant’s N, P, K (potassium) requirements which are going to be fertilised. Energy balance of the system has to include the total energy input (direct and indirect) (Mikkola and Ahokas, 2010; Navickas et al., 2011a) of the full cycle covering soil cultivation, biomass production, anaerobic digestion and fertilisation of soil by digestate.

The aim of this study is to determine an energy efficiency of conversion of mixture from fish (salmon) processing co-streams and cattle manure to biogas and fertilisers.

Methods

For the energy analysis the farm system, corresponding 600 milking cows producing 12000 t/year of manure having 600 ha of cultivated land, has been used. The system assessed was the anaerobic digestion of fish co-stream (salmon backbones after filleting) and cattle manure on a regional scale while co-digestion of other feedstock was not considered. The analysis of added value of fish backbones was done by comparing two different scenarios. Scenario 1 represents the system of the fertilisation of arable land intended for summer barley growing. According to the barley nutrient requirements (N110; P40; K80 kg/ha) analysed system using cattle manure (12 000 t/year) and additionally mineral fertilisers of 300 t per year (for 600 ha). The farm land (600 ha) is divided in two areas – 400 ha fertilised with a cattle manure with additional P-fertilisers while the other 200 ha is fertilised with mineral fertilisers only. The application rate of cattle manure is 30 t/ha and additionally 484 kg/ha of mixed fertilisers (ammonium nitrate; ammonium di-hydrophosphate; potassium chloride). The area of 200 ha is fertilised by application of 534 kg/ha of mixed fertilisers (ammonium nitrate; ammonium di-hydrophosphate; potassium chloride). Mineral fertiliser is
transported 100 km from the supplier to the farm by lorry with transportation capacity of 24 t. The storage of 500 m² is
designed for fertilisers at the farm. From storage fertilisers are transported to the fields which are 10 km away by tractor
(155 HP) with 13 tons trailer. Liquid manure is stored at 8000 m³ tank from which is littered by injecting spreader with
capacity of 30 m³ and 24 m width.

The second scenario (Scenario 2) – arable land is fertilised with a digestate obtained after anaerobic codigestion
of mixtures from fish backbones and cattle manure. In the Scenario 2, the mass fish backbones is estimated to be 2400 t
per year and 12000 t/year of cattle manure (corresponding to the farm of 600 milking cows). According to the barley
nutrient requirements (N110; P40; K80 kg/ha), analysed system do not requires addition of mineral fertiliser. The
Scenario 2 is designed in such way, that chemical composition of feedstock comprises the necessary N, P, K norm for
winter barley.

Liquid manure and salmon backbones are mixed at a ratio 1:5 (by mass proportion 80% of manure, 20% of
backbones) together before feeding to the digester. Anaerobic digestion process was assumed to be a wet, single stage,
continuously fed process operating at mesophilic temperature (+38 °C) and an organic loading rate of 2 kg VS m⁻³ day⁻¹
with TS content at input of 12.1 %. The volume of the anaerobic digester is 2300 m³. Parameters associated with the
fish backbones and animal manure treated within the AD plants with a biogas yield of 88 m³/t mixture and methane
content of 65 %.

High concentration of nitrogen (62357 mg/kg) and phosphorus (12912 mg/kg) was found in backbones after
salmon filleting (Table 1). Therefore the codigestion of salmon backbones and cattle manure was considered as an
optimal for improvement of the efficiency of biogas plant and fertilisation quality of digestate as well. Mixing liquid
(6.28% TS) cattle manure with comparable dry (41.58% TS) fish backbones in certain percentage allows to get
desirable for anaerobic digestion TS concentration (10–20% TS).

### Table 1. Chemical composition of salmon backbones and cattle manure

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Results of chemical analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Salmon backbones after filleting</td>
</tr>
<tr>
<td>Total solids (TS) %</td>
<td>41.58</td>
</tr>
<tr>
<td><strong>In total solids:</strong></td>
<td></td>
</tr>
<tr>
<td>Organic material (volatile solids VS) %</td>
<td>92.48</td>
</tr>
<tr>
<td>Organic carbon (C) %</td>
<td>6975</td>
</tr>
<tr>
<td>Total nitrogen (N) mg/kg</td>
<td>62357</td>
</tr>
<tr>
<td>Total phosphorus (P) mg/kg</td>
<td>12912</td>
</tr>
<tr>
<td>Total potassium (K) mg/kg</td>
<td>5583</td>
</tr>
<tr>
<td>Calcium (Ca) %</td>
<td>2.29</td>
</tr>
<tr>
<td>Magnium (Mg) %</td>
<td>0.06</td>
</tr>
<tr>
<td>Cuprum (Cu) mg/kg</td>
<td>7.73</td>
</tr>
<tr>
<td>Zink (Zn) mg/kg</td>
<td>32.0</td>
</tr>
<tr>
<td>Manganese (Mn) mg/kg</td>
<td>5.50</td>
</tr>
<tr>
<td>Ferrum (Fe) mg/kg</td>
<td>20.4</td>
</tr>
<tr>
<td>Borum (B) mg/kg</td>
<td>17.9</td>
</tr>
<tr>
<td>Sulphur (S) mg/kg</td>
<td>294</td>
</tr>
<tr>
<td>Fat %</td>
<td>54.2</td>
</tr>
</tbody>
</table>

It was assumed that digestate generated from the biogas plants are compliant with the Publicly Availably
Specification (PAS) 110 (WRAP, 2010) and the Anaerobic Digestate Quality Protocol (WRAP, 2009), and can
therefore be considered as a product and utilised as a fertiliser within agriculture, forestry or soil/field grown
horticulture. The whole digestate is transported to the fields for fertilisation of barley. Transportation of digestate
was undertaken using tractor with capacity of 17 m³. Tractor velocity when loaded 15 km/h and empty – 25 km/h. Distances
for transporting digestate to the nearest arable land were assumed to be 10 km (arable land belonging to the farm).

At biogas plant the storage place of 500 m² is modelled for the storage of delivered fish backbones. Storage
conditions are at ambient temperatures (+10 °C). Approximate road distances between the fish processing plant and the
digestion facility were calculated in order to determine approximate by-products transport distances (by 24 t lorry). The
distance was assumed to be 100 km. Collection and transportation of fish by-products from processing plant to the
biogas plant, which is at the cow farm, is included in the study.

The energy balance of the analysed system can be expressed as the difference between input and output and can
be defined by the equation:

\[
E_{\text{final}} = E_{\text{BM}} - E_{\text{input}},
\]

where: \(E_{\text{final}}\) – final useful energy, MJ/ha;
\(E_{\text{BM}}\) – energy potential of biomass, MJ/ha;
\(E_{\text{input}}\) – energy input of the system, MJ/ha.
The energy potential of biomass is defined as potential biogas production from cattle manure and fish backbones and has been determined according to the methodology explained by Navickas et al. (2005) based on farm land area. According to the laboratory experiments (not published) performed at the Biogas laboratory of Aleksandras Stulginskis University the biogas yield from mixture of cattle manure and salmon backbones has been considered 88 m$^3$/t from feedstock with methane concentration of 64.9% in the biogas.

The various equipment and machinery are used for technological operations and processes therefore the total energy input can be expressed by the equation:

$$E_{\text{input}} = \sum_{i} E_{TEi},$$

where: $E_{TEi}$ – total energy inputs, MJ/ha;

$i$ – number of technological operation or processes.

The methodology of energy input for technological operations is presented and described by Navickas et al. (2013b) and Navickas et al. (2011a).

Total energy input is defined as direct and indirect energy input of the technological operation:

$$E_{TEi} = E_{di} + E_{indi},$$

where: $E_{di}$ – direct energy input, MJ/ha;

$E_{indi}$ – indirect energy input, MJ/ha.

**Results and discussions**

Analyzing the full farm system, the delivery, storage and spreading on the field of mineral fertilisers, biomass conversion to biogas, littering of liquid manure or digestate to the field has been considered.

Results of the system defining the process of manure and mineral fertiliser application on field are presented in Figure 1 (Scenario 1) and fish backbones and manure co-digestion process flow diagram (Scenario 2) in Figure 2.

![Process Flow Diagram](image)

**Figure 1. The process flow diagram with cattle manure and mineral fertiliser (N, P, K) application on field (Scenario 1)**

Results show that the total direct energy input at Scenario 1 is 449 MJ/ha and in Scenario 2 – 848 MJ/ha. The distribution according to the processes is presented in Fig. 3 where the highest energy input is found for manure spreading on the field (335 MJ/ha) (Scenario 1) while other technological processes (delivery and storage of mineral fertilisers, mineral fertilisers delivery to field and spreading) varies from 12.1 MJ/ha to 42.1 MJ/ha.
Figure 2. The process flow diagram with application of digestate of fish backbones and manure on field (Scenario 2)

Different situation is at Scenario 2 where the only four inputs (delivery of fish backbones, storage of fish backbones, spreading of liquid digestate and anaerobic digestion). Additionally there is fish backbones delivery (100 km) from the fish processing place to the storage place which is 165 MJ/ha. Due to the high quantity of fish backbones (2400 t) the processes (unloading and loading for delivery to the biogas plant by 155 HP tractor) are high energy consuming with input of 280 MJ/ha. It is assumed that the fish backbones is delivered by europallets (600 kg on one pallet) therefore for the unloading from the lorry and loading to the trailer it is necessary to operate with 8000 pallets. It takes 300 working hours and fuel consumption is 4710 liter. The energy input of liquid digestate spreading on the field (402 MJ/ha) is found the similar to manure spreading as the product quantity changes – 12000 t/year cattle manure and 14400 t/year of cattle manure and fish backbones digestate.

Figure 3. Total direct energy input distribution according to the processes for Scenario 1 and 2

The anaerobic digesting has energy input of magnitude of 10 times. The energy input for anaerobic digesting is applicable only for Scenario 2 and has the total direct energy input 3722 GJ for the farm and 6.2 GJ/ha. The high energy input is associated with anaerobic digester of 2300 m$^3$ and many various technological operations. Input of 64.6 MJ/t electric power was found in anaerobic digestion processes.

The total indirect energy input is higher for Scenario 1 (13.0 GJ/ha) in comparison with Scenario 2 – 0.73 GJ/ha. The distribution of indirect energy according to the processes is presented in Fig. 4. The mineral fertilisers have a very high
indirect energy indicator – 35.3 MJ/kg N-fertiliser, 15.8 MJ/kg P-fertiliser and 9.3 MJ/kg K-fertiliser. The highest indirect energy input is found for mineral fertilisers (12.7 GJ/ha) while the all other inputs are 0.32 GJ/ha only (Scenario 1).

Figure 4. **Total indirect energy input distribution according to the processes for Scenario 1 and 2**

The biogas plant has input of 304 MJ/ha of indirect energy. The delivery of mineral fertilisers (6.9 MJ/ha) has lower energy input compared to delivery of fish backbones (68.1 MJ/ha) due to the different quantities (mass) – 300 t/year in Scenario 1 and 2400 t/year in Scenario 2. Other processes was found to be similar or at the same magnitude (storage of liquid manure and spreading on the fields).

Finally, total energy input for Scenario 1 is 13.4 GJ/ha and for Scenario 2 – 7.7 GJ/ha. The total energy input in Scenario 2 is 27% lower compared to Scenario 1. However the energy balance shows that Scenario 1 has negative (13.4 GJ/ha) energy balance because there is no energy production (Fig 5.). Scenario 2 has a positive energy balance with useful energy of 40.5 GJ/ha.

Figure 5. **Energy balance of Scenario 1 and 2**

An anaerobic digestion of fish backbones (filleting co-stream) and application for fertiliser generates 5.3 times more energy than was consumed in all technological processes and transportation. Therefore, technology when arable land is fertilised with a digestate of mixtures from fish co-streams and cattle manure after anaerobic codigestion has a high potential for industrialisation.
Conclusions

1. It is determined that direct energy input depends on the applied technology and for Scenario 1 is 0.45 GJ/ha and for Scenario 2 – 7.05 GJ/ha, while indirect energy input 13.0 GJ/ha and 0.68 GJ/ha respectively.

2. Use of fish backbones (salmon filleting co-stream) for biogas generation and application of substrates as land fertilisers generates additional energy value for the farm 40.5 GJ/ha. Technological processes and transportation consumes about 7.7 GJ/ha.

3. The additional energy value of fish industry co-streams could improve the energy balance of the farm and it has a high potential for industrialisation.

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Prospects for Development of Biomass Production in Agricultural Holdings of North-Eastern Poland

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Abstract

The need to fulfil environmental commitments regarding the energy policy in the European Union has resulted in an increased interest in the use of renewable sources of agricultural origin. This necessitates re-orientating the Member States' energy policies. On the other hand, due to the increased demand for energy, and the intensification of trends such as an increase in prices in the fuel and energy market, it is extremely important to identify the prospects for the non-food use of biomass originating from agricultural holdings, including the intended use thereof for energy purposes. The aim of this paper is to present the prospects for development of biomass production in agricultural holdings for energy purposes. Opinions regarding the determination of the above-mentioned prospects were collected from an identified group of farmers engaged in cultivation of such crops. The research shows that agricultural holdings with the biomass production in Poland and North-Eastern Poland are very few. The research shows that the barriers to the development of production of agricultural biomass for energy purposes are mainly economic in nature, and result from, inter alia, the volatility of prices and the existing difficulties to sell raw materials (in the opinion of almost 60% of respondents), and the low level of prices which fail to guarantee profitability of production (in the opinion of almost 40% of respondents). Therefore, farmers are awaiting support, in particular in a form of crop area payments (in the opinion of almost 25% of respondents), which, in their opinion, may improve profitability of production and encourage other farmers to take it up at the same time. It is to be expected that in the short term of next several years, it will become an important profile of production for many agricultural holdings, but today it isn't popular the direction of production in Poland. However, a condition for the further development of such an activity is to solve the problem of the organisation of biomass processing, and to reconcile such type of production with food-related purposes of agriculture.

Introduction

A new challenge for the European Union Member States, including their agriculture, is the environmental commitment as regards the energy policy. The outlined quantitative targets concern the reduction in greenhouse gas emissions by 20% from 1990 levels, and the reduction in energy use by 20% as compared to the projected levels for the EU for 2020. One of the ways to achieve those objectives is to make use of renewable energy sources of agricultural origin for energy generation. For Poland, the share of energy from renewable sources (RES) in the total consumption thereof must increase to up to 15% in 2020, and to 20% in 2030. It is also planned to achieve in 2020 the 10% ceiling of share of biofuels in the biofuel market, which should result in an increase in the use, for transport purposes, of up to 10% of energy obtained from renewable sources (Polityka energetyczna..., 2009).

In view of the above-mentioned commitments, one of the principal paths of Poland's energy policy within a time span of several years to come will be pursuing an increase in the level of the use of renewable energy sources. On average, in the European Union in 2010, a total of 634 TWh of energy was obtained from renewable sources, which accounted for approx. 20% of the total amount of energy generated. Within the structure of the RES, water power accounted for over 50%, but other sources, e.g. wind (25%) and biomass (20%), also had a significant share (EU energy trends..., 2010). Long-term projections forecast rapid development of the sector of energy obtained from renewable energy sources (Urbański, Tarnowska, 2011). Although the energy obtained from renewable sources is not widely popularised in Poland, growing interest therein of both the potential producers and consumers thereof has been already noticeable for several years.

Due to the rapid development of demand for energy, and the intensification of trends such as an increase in prices in the fuel and energy market, the determination of a growing number of countries and their governments to implement the climate policy, the progressive liberalisation of the market, and the growing demand for information, it is important to identify the prospects for the non-food use of biomass originating from agricultural holdings, including the use thereof for energy purposes. This is an important problem because in Poland agricultural holdings involved in the production of biomass for energy purposes and information about them is not enough.

The aim of this paper is to present the prospects for development of biomass production in agricultural holdings, including the intended use thereof for energy purposes. Opinions regarding the determination of the above-mentioned prospects were collected from an identified group of farmers engaged in cultivation of such crops.

Object and research methods

From the territorial perspective, the scope of the research covered individual agricultural holdings operating in Warmińsko-Mazurskie province. The sample consisted of 122 owners of holdings as registered by agricultural advisors of the Warmińsko-Mazurski Agricultural Advisory Centre (W-MODR) in Olsztyn as holdings cultivating crops to be used for biomass production. The group under research consisted of all persons identified as producers of biomass to be used for energy purposes. The field research, using the standardised interviewer questionnaire, was conducted in December 2012. Additionally, the participant observation was also employed, where the researcher becomes an
observer and an accepted participant of the community under research. This allowed the author to verify certain disadvantages of the selected research method, in accordance with the principle of scientific objectivity and obtaining reliable information. The paper also made use of secondary data, i.e. information included in the relevant literature and source documents.

The average age of the respondents was almost 30 years. Men were predominant, and accounted for 80.33% of the group under research. Every second farmer (50.82%) has received higher education, while more than every third of them (36.07%) has obtained secondary schooling. The research participants mainly held university degrees and diplomas of agricultural schools.

The average area of holdings of the producers of biomass to be used for energy purposes amounted to 199.21 ha, including the average area of 180.10 ha for agricultural land (AL) (while the median of the total holding area of the group under research amounted to 93.5 ha (for AL, 83.5 ha)). The minimum area of a holding under analysis amounted to 12.6 ha, while the maximum area was 1,988.0 ha. Table 1 presents the structure of the area under crops to be used for biomass production in 2012 in holdings of the farmers participating in the research. According to the information obtained from respondents, perennial energy crops were cultivated in 65% of holdings. That was the group in which the average acreage under those crops amounted to 30.05 ha (a median of 12.16 ha). The structure of the acreage planted (with a significant area under crops) also included cereals (24.59%, an average area of over 50 ha, a median of 20 ha) as well as rape and turnip rape (13.11%, on average almost 80 ha, a median of 67.75 ha). The remaining crops, i.e. papilionaceous plants with grasses, maize, and grasses, were of minor importance (Table 1).

<table>
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<th>Specification</th>
<th>Percent of indications</th>
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<th>Average</th>
<th>Median</th>
<th>min</th>
<th>max</th>
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<td>50.21</td>
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<td>200.00</td>
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<td>4.92</td>
<td>3</td>
<td>26.00</td>
<td>25</td>
<td>5.00</td>
<td>48.00</td>
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<tr>
<td>maize</td>
<td>3.28</td>
<td>2</td>
<td>180.00</td>
<td>180.00</td>
<td>180.00</td>
<td>180.00</td>
</tr>
<tr>
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<td>8.20</td>
<td>5</td>
<td>52.50</td>
<td>40.75</td>
<td>11.27</td>
<td>96.08</td>
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<td>8</td>
<td>79.43</td>
<td>67.75</td>
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<td>30.05</td>
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<td>0.60</td>
<td>330.00</td>
</tr>
</tbody>
</table>

Table 1. Structure of the area under crops to be used for biomass production in 2012 (ha)

Source: own research

It should be noted that 72 % of the holdings were not engaged in animal production; moreover, products and residues from such an activity in the remaining holding were not intended to be used for energy generation.

Results of research

More than 65% of respondents concluded that within a time span of the next 2–3 years they intended to increase, in the structure of the acreage planted, the share of crops to be used for energy purposes; primarily, that includes crops such as cereals (21.31% of indications), common osier (16.39%), and rape (11.48%). The remaining farmers did not indicate such plans. According to the opinions of the farmers in that group, the discouragement was caused by problems such as low profitability, and absence of institutional support.

The growing demand for energy, and, at the same time, dwindling fossil resources, i.e. coal, crude oil and natural gas, along with the growing environmental degradation, result in the growing interest in energy from renewable sources, including biomass from agricultural holdings. According to Korycińska (2000): “most of the assessments of the biomass potential, as conducted so far, indicate that out of various types of biomass, it is the agricultural one that has the biggest energy potential”. Under Directive 2009/28/EC on the promotion of the use of energy from renewable sources, agriculture is considered to be, among other things, a producer of renewable energy. This is important as regards the agricultural resources in our country, since, as noted by, inter alia, Faber (2008): “Poland has approx. 0.41 ha of agricultural land per capita, while for the so-called “old” Union countries, the value concerned is only 0.19 ha. Therefore, Poland has always been seen as a country likely to provide a significant share in the production of biomass for energy purposes in the EU. According to estimates, Poland’s potential for the cultivation of energy crops amounts to from 1.0 to 4.3 million ha by 2020”. However, one also needs to remember the food-related purposes of agriculture. According to the experts of the Institute for Renewable Energy (IEO), provisions of the National Renewable Energy Action Plan (NREAP) concerning the areas to be brought under the cultivation of e.g. rape (which is a raw material for the production of biodiesel), indicate that the acreage of production of that crop for food and fuel purposes has been significantly exceeded (1.10 million ha). As a result, the experts expect that there will be a shortage of approx. 1 million ha for the production of rape, and Poland will be forced to import significant amounts of either raw

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3 When the median is less than the arithmetic mean, it means that the value of that feature in most statistical units is less than the arithmetic mean.


6 The limit value as provided should not be exceeded for phytosanitary reasons.
material or oil, if the intended purpose of biodiesel production is achieved. On the other hand, the demand for cereals for the purpose of bioethanol production, as indicated in the NREAP, may be fully met (Określenie potencjału..., 2011).

In agricultural holdings, the main sources of biomass resources are as follows:
- crops cultivated on the so-called surplus agricultural land – the biomass may be sourced in a situation where demand for food and feed is met;
- crops cultivated on degraded land – biomass may be produced on the formerly afforested areas or areas otherwise degraded or peripheral, which are still suitable for being re-used for energy purposes;
- agricultural residues – residues from agricultural production and agro-food processing;
- solid animal waste (Hoogwijk, 2004).

The cultivation of biomass for energy purposes may, in a long term, be sustainable in relation to the scale of energy generation and energy needs, and it also may become a source of additional income and lead to an increase in employment in rural areas. It is also believed that it may contribute to the efficient use of environmental resources. That opinion is confirmed by the research results as obtained. According to the respondents, energy originating from biomass (being one step behind the solar energy in the rank) is one of the key development directions for measures associated with the demand for energy. In the opinions of farmers participating in the survey, the remaining trends of the demand for energy from renewable sources are, in descending order and in terms of significance: wind, water, geothermal and biogas energy. On the other hand, they are of the opinion that the use of crude oil, coal and lignite resources is, from the perspective of power industry development, becoming less and less significant (Fig. 1). It needs to be noted that according to the Central Statistical Office (GUS) data, in Poland, in the years 2006–2011, it was the energy from solid biomass that accounted for the biggest item of the balance of renewable energy. The share of biomass in the renewable energy carriers in the total sourcing of energy from renewable sources in 2011 amounted to approx. 85%, while the solar energy amounted to only 0.13%, and the water power to 2.58%. Furthermore, account must be taken of the public statistical data which indicates that the share of energy from renewable sources in the total sourcing of primary energy in the EU accounts for the average of 20% (EU energy trends..., 2010), while in Poland for 11%, with an upward trend both in our country and throughout the Community (Energia ze źródeł..., 2012).

Figure 1. Trends in the demand for energy from renewable sources within a time span of the next several years, in the respondents’ opinions (based on a score of 1 to 5, with 5 being the maximum)
Source: own research.

Numerous restrictions to the development of the entire RES industry include the economic, technical, logistical, environmental, social, cognitive, legal and commercial problems, as well as the problems associated with the availability and ownership of land, the danger of deforestation in certain areas, disequilibrium in the energy balance, increasing conflicts, or the competitiveness of that direction of farmers’ economic activity with the production of agricultural raw materials intended for food purposes.

While identifying the determinants of the development of biomass production for energy purposes in agricultural holdings, the respondents primarily indicated the volatility of prices in the market (approx. 60% of
indications) as well as the need for ensuring such prices of the raw material that would guarantee profitability of production (39.34%). Those claims result from, *inter alia*, the actual low level of the organisation of entities engaged in biomass processing for energy purposes. Such circumstances interfere with striking the balance between the demand for and supply of biomass.

The fact that the organisation of modern technological chains of biomass processing requires significant capital expenditure still makes the conventional carriers a very attractive source of raw materials. Therefore, while fulfilling the objectives of the adopted EU energy and climate strategy, the measures aimed at promoting the use of energy from renewable sources through applying appropriate economic mechanisms are of particular importance (Energia w gospodarstwie..., 2011). In the opinion of every fourth agricultural producer participating in the research, it is the absence of direct payments to such crops that is the main barrier to the development of this type of production. The relatively high expenditure associated with the production of crops for biomass, in a situation of either low or even negative profitability of cultivating other agricultural crops, restricts the agricultural producers’ interest in that particular profile of production. Such circumstances lead to the situation where farmers are awaiting for appropriate mechanisms of financial support in a form of, for instance, area payments to the production, which would provide compensation for the low economic efficiency of cultivating crops intended for energy purposes. The form of support being discussed here seems a sufficient argument for the farmers’ interest in the cultivation of such crops. Although there are other possibilities for financial support to the use of RES in rural areas, they mainly apply to the development of infrastructure and processing, and not to the direct support to the crops. Another factor as found important by 18% of respondents, which determines the development of biomass production for energy purposes in agricultural holdings, is the appropriate State policy along with regulations. That is an issue of the efficient development of the power industry with the use of RES, since the current status of legal solutions is considered, in the group of biomass producers under analysis, to have an adverse effect on the increase in the share of the RES energy. The remaining determinants as indicated by the farmers were associated with the following issues: appropriate systems of cultivation and harvesting, and the distance from the outlets. Account should be taken of the fact that the respondents, in their assessments, did not attach a particular value to issues such as an increase in prices in the market of alternative raw materials (e.g. crude oil) as compared to biomass, and the need to protect the environment being degraded through the sourcing of minerals (Fig. 2).

Figure 2. *The factors which, in the respondents’ opinions, determine the development of biomass production for energy purposes in agricultural holdings (% of respondents).* The remaining ones include: high price of crude oil; environmental protection – RES being in vogue; restricted access to the sources of knowledge on the possibilities for production and use of biomass for energy purposes; technical infrastructure; and the possibility for development of problematic areas.

Source: own research

Along with the process of progressive diversification of energy sources, an important factor of the development of crops with the intended use of biomass for energy purposes is the support provided by a variety of institutions. Another serious problem has been the rudimentary system of information flow, and the relatively low level of the farmers’ knowledge on the issues of crop selection, cultivating crops, or the possibilities for and forms of the sales of
biomass (however, that particular issue was noted by only one respondent – Fig. 2). In the opinions of 73% of the farmers participating in the survey, the major role in the transfer of knowledge on the development of biomass production should be played by the provincial Agricultural Advisory Centres (WODR), while in the view of 47.5% of respondents, by the ARMA (Agency for Restructuring and Modernisation of Agriculture) and AMA (Agricultural Market Agency). A similar number of respondents (44.26%) indicated the important role in that regard of local governments, especially as the local government sector frequently benefits from EU funds which may be designed to be used for the development of infrastructure associated with the organisation of the system of sourcing energy from renewable sources (Fig. 3).

In general, the need for support through specially established institutions dealing with the RES issues was indicated by every third respondent, while every fifth farmer under the research noted that it is the Agricultural Chamber that is an important element of the system of transfer of knowledge on the production of biomass for energy purposes, and the processing thereof (Fig. 3). It may be concluded that biomass producers most frequently seek for support to their actions in the immediate vicinity.

Figure 3. Institutions and organisations which, in the biomass producers’ opinions, should support measures aimed at propagating the use thereof for energy purposes (% of respondents, abbreviations: AAC – Agricultural Advisory Centre (ODR); ARMA – Agency for Restructuring and Modernisation of Agriculture (ARiMR); AMA – Agricultural Market Agency (ARR); PFEPWM – Provincial Fund for Environmental Protection and Water Management (WFOŚiGW)
Source: own research

Conclusions

The prospects for the development of cultivation of crops with the intended use for energy purposes depend on numerous factors, both internal (associated with the current organisational level of the agricultural sector) and external conditions, including the legal solutions. The research shows that agricultural holdings with the biomass production in Poland and North-Eastern Poland are very few. In the farmers’ opinions, the barriers to development of agricultural production of raw materials for energy purposes are mainly economic in nature, and result from, inter alia, the volatility of prices, the existing difficulties to sell raw materials (in the opinion of almost 60% of respondents), and the low level of prices which fail to guarantee profitability of production (in the opinion of almost 40% of respondents). Therefore, farmers are awaiting support, including, in particular, in a form of crop area payments (in the opinion of almost 25% of respondents), which, in their opinion, may improve profitability of production and encourage other farmers to take it up at the same time. Certainly, the important factor affecting the further development of the production profile in question are the clearly defined objectives of the energy and agricultural policy, and the fulfilling thereof to the satisfaction of biomass producers (in the opinion of almost 20% of the respondents).

7 In the years 2007–2009, ARMA provided financial support to farmers for the cultivation of crops to be used for energy purposes. The authority responsible for supervising the processing of the above-mentioned crops to final energy products was AMA.
Furthermore, account should be taken of the fact that the EU under the CAP, despite having previously adopted payments to the energy crops, has withdrawn from that type of support. It can be assumed that obtaining new, renewable energy sources requires both the appropriate policy governing those markets, and the introduction of economic incentives, and, primarily, the establishment of an efficient system of the flow of information and knowledge on the RES. Out of the institutions supporting the entities within the chain of biomass production and processing for energy purposes, the most frequently indicated ones include the Provincial Agricultural Advisory Centres and State Agencies supporting the development of agriculture and rural areas (e.g. ARMA and AMA), and the local governments and the Agricultural Chamber.

As may be seen, the objectives of the European Union’s energy policy are clearly defined. However, the requirement for an increase in the use of the “green energy” within a time span of the next two decades results in problems with the fulfilling thereof, which arise in many countries. One of the ways to fulfil those commitments is to use biomass, and one of the main sectors of economy supplying that particular raw material is agriculture. In conclusion, it must be concluded that currently biomass, as a renewable energy source, is used to a small extent, despite the actual significant potential thereof. It is to be expected that in the short term of next several years, it will become a new important profile of production for many agricultural holdings. However, a condition for the further development of such an activity is to solve the problem of the organisation of biomass processing, and to reconcile such type of production with the field of food production.

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Evaluation of Ash Content in Grass Plant Biomass used for Energy Production

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Abstract

One of the most topical problems in agriculture is related to the production of high-quality perennial grass plants having particular chemical content that would ensure utilisation thereof in the production of bioenergy. Productivity and chemical content of grass plants is largely influenced by fertilisers: their types (nitrogen mineral fertiliser, vermicompost) and norms, especially by ones used during the growing period. Nitrogen (N) is significant for plant life processes, and thus it also influences crop yield. Production of heat requires plants producing high biomass yield, having high combustion ability, high heat output and low ash content; therefore research aims at studying ash content in reed canary grass and tall fescue biomass used for the production of biofuel.

Scientists have discovered that reed canary grass (RCG) effectively reacts on the treatment with N mineral fertilisers. Analysis of RCG biomass yield correlation with N doses indicates that increase in the N dose (above 120 kg ha\(^{-1}\)) reduces the biomass dry weight coefficient by 0.02%. Whereas lowest ash contents were recorded for N90 dose (2.98%), moreover if N dose is increased above 120 kg ha\(^{-1}\), the ash content grows. Ash content is one of the main indicators in heat production; moreover, standard EN 14961-2 stipulates that its norms can not exceed 1.5%. Higher ash content causes problems in automatic combustion process. Analyses of ash content in RCG biomass depending on doses of N fertiliser indicate the lowest indicators with N90 dose – 2.98%; moreover, an N dose is increased above 120 kg ha\(^{-1}\), the ash content is growing. In its turn, the most suitable tall fescue indicators were found with N180 dose 7.93%; ash content in biomass increases and reaches 8.83% if plants are treated with vermicompost, and ash content in biomass not fertilised comprises 8.41%.

Introduction

EU politics and economy encourage utilisation of grass plants for the production of energy sources, namely biofuel and biogas. Economic viewpoint suggests that grass species producing high and stable biomass yield, ones that are perennial and permanent, modest in respect to growing conditions, as well as resistant to cold, drought and other adverse environmental factors are the most suitable for this purpose.

Under the specific climatic conditions of Latvia, heat supply is significant part of the energy sector, consuming approximately 62% of the total fuel volume (Projekts, 2012). Heat power industry allows acquiring local renewable resources with the highest efficiency (Atjaunojamo, 2012). At the end of 2010, installed electric capacity of biomass and biogass power plants of all types in Latvia comprised 22 MW (Biomasa, 2012).

Use of biomass in the energy production is a precondition crucial to avoid ecological disasters in future and to compensate increasingly growing shortage of fossil energy resources (Finell et al., 2011, Energy, 2009). Effective use of nutrients is of great significance for sustainable agricultural production. Sufficient amount of nutrients ensures favourable conditions for long-term and stable use of soil resources and high crop yield. Fertilisers along with climatic and soil conditions are vital for RCG productivity and yield quality. Nitrogen (N) quantities and use efficiencies as well as energy input are important for environmental impact and production of energy crops. On the other hand, the high targets set in Europe for the production of biofuels will require high energy yields and efficient use of available agricultural land (Lewandowski and Schmidt, 2006). One of the most topical problems encountered in Latvia agriculture is the acquisition of high-quality perennial grass plants with definite chemical content, ensuring that they may be used for the production of bio-energy – solid fuel (pellets, briquettes). One of the solutions for this problem may be based on the fact that scientists (Energy, 2009, Lazdiņa et al., 2008, Lewandowski, Schmidt, 2006) have learned that RCG effectively reacts on fertilising with nitrogen. Nitrogen is significant for plant life processes and thus also for the yield of crops. Heat production requires plants with high biomass yield, combustion ability, heat output and low ash content. Ash content characterises amount of non-combustible minerals in fuel. Ash consists of minerals that remain as fuel is burnt, i.e., those are inorganic substances (Belicka et al., 2009, Beloselskyj, Soljajov, 1980, Cars, 2008, Platače, Adamovičs, 2012). Ash content is one of the key indicators that in line with standard DIN 51731 should not exceed 1.5% (Quality standards, 2009).

Higher ash content causes problems with combustion automation, moreover thermal capacity of such pellets is by 600-1000 kJ kg\(^{-1}\) lower (e.g., thermal capacity of bark briquettes with ash content 14% comprises 16554 kJ kg\(^{-1}\), while DIN 51731 sets that thermal capacity should reach at least 17500 kJ kg\(^{-1}\)) (Tardenaka, Spince, 2006).
Alternative heat source in many countries is energy crops (Adamovičs, 2007, Adamovičs, 2012, Bridgeman et al., 2008, Heaton et al., 2004, Klass, 2004, Heaton et al., 2004; Saballos, 2008; Sander, Andren, 1997, Platače, 2013); and one of the plants used for biomass is RCG (Phalaris arundinacea) that is widely cultivated in Scandinavian countries.

Ash content in biomass depends on various factors, e.g., plant specie: switchgrass – 8.3%, (Madakadze et al., 1999), giant reed – 6.1%, miscanthus – 2.3%, cardoon – 17.4%, wood pellets – 0.50% (Dahl J., Obernberger, 2004).

Tall fescue (Festuca arundinacea Schreb.) is a plant meeting all heat production requirements and is cultivated over various climatic conditions (Chapman, 1996). It is Eurasian grass grown in many and different regions, since natural populations thereof may be seen from northern Africa to northern Europe, in sites varying from arid to very wet. Tall fescue is more persistent to drought, as compared to other cool-season grasses. e.g., perennial ryegrass or Kentucky bluegrass (Huang and Gao, 2000). Tall fescue is very responsive on fertilisation with N (Easton et al., 1994).

Ash content in wood fuels does not exceed 1.4%, in peat pellets and briquettes it varies between 1.27% and 5%. It may be explained by the fact that peat content varies rather greatly and may contain various mineral substances. Ash content in cereal straw among various species varies between 5% and 8% (Kaķītis et al., 2010). Bearing in mind the low ash content of timber, it may be useful to mix it with biomass (with high ash content) directly before making pellets, since that would allow acquiring pellets with lower ash content; and thus use of biomass with high ash content for production of energy (biofuel and heat) may be facilitated.

Researchers have discovered that production of solid fuel from plant biomass is one of the technologies used for production of biofuel and heat (Adamovičs et al., 2009, Adamovičs et al., 2012, Lazdiņa et al., 2008). Therefore the research aims at evaluating RCG and tall fescue ash content depending on fertiliser types and norms and suitability of this biomass for the production of biofuel.

**Materials and methods**

Within the territory of Latvia RCG biomass currently is considered to be one of the alternative sources for pellet production in Baltics and Northern Europe. This grass plant is characteristics with persistence to local climatic conditions and high biomass yield from 1 ha.

Research objects: RCG (Phalaris arundinacea) and tall fescue (festuca arundinacea schreb.) that are perennials yielding for 8–10 years, plant length up to 1.5 m, they are modest in terms of requirements for soil and may grow in marginal soils, moreover they are suitable for cultivation in moisture meadows, with strong root system and excels also with durability against draughts cold tolerance. Soil type: lesivated brown soil. The field trial was carried out in 2011–2012 in Research and Study farm "Peterlauki" (56°53'N, 23°71'E) of the Latvia University of Agriculture, in the sod calcareous soils pHKCl 6.7, containing available for plants P 52 mg kg⁻¹, K 128 mg kg⁻¹, organic matter content 21 to 25 g kg⁻¹ in the soil. Main fertiliser: background P₂O₅- 80; K₂O- 120 kg ha⁻¹ (Table 1). Total sowing norm in versions: 1000 germinant seeds per 1 m². Usage type: mowing two-three times. Fertiliser used until now was mineral (ammonium nitrate, complex N: P: K). Energy crop researches were conducted in Training and Research Farm “Peterlauki” of the Latvia University of Agriculture, using both grass plants and treating them with 9 different fertilisers.

For the first time in Latvia influence of organic fertiliser – vermicompost and vermisil – on productivity and chemical content of grass will be researched. Vermicompost is organic fertiliser that is processed with organic agricultural waste earthworms (usually Eisenia Foetida and Lumbricus Rubellus) and bacteria or other organisms (vermin, fungi etc.). Vermisil is fertiliser containing humus substances acquired from vermicompost and is used to improve plant growth.

<table>
<thead>
<tr>
<th>Nr.</th>
<th>Fertiliser versions (kg ha⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>N0P0K0 (control)</td>
</tr>
<tr>
<td>2</td>
<td>P₂O₅ - 80; K₂O - 120 (background)</td>
</tr>
<tr>
<td>3</td>
<td>F+N30</td>
</tr>
<tr>
<td>4</td>
<td>F+N60</td>
</tr>
<tr>
<td>5</td>
<td>F+N90</td>
</tr>
<tr>
<td>6</td>
<td>F+N120 (60+60)</td>
</tr>
<tr>
<td>7</td>
<td>F+N150 (75+75)</td>
</tr>
<tr>
<td>8</td>
<td>F+N180 (90+90)</td>
</tr>
<tr>
<td>9</td>
<td>Vermicompost - 10 t ha⁻¹</td>
</tr>
</tbody>
</table>

Ash content in different composition samples was found out in the agricultural scientific laboratory for agronomic analyses of the University of Latvia in compliance with the ISO 5984: 2002/Cor 1: 2005 standard. For each sample three parallel experiments were carried out, repeating each tested combination three times. The correlations were analyzed as linear or polynomial regressions, and graphs were made using MS Office program Excel.
Results and discussion

The results acquired show that biomass of both RCG and tall fescue has high ash content. Slightly lower ash content was observed for RCG – from 7.02% to 8.82%, while in tall fescue it was slightly higher – from 7.93% to 8.92% (Fig. 1). The highest ash content was recorded in tall fescue with fertiliser N0P0K0 (control) – 8.92 ± 0.10 %, while in RCG with fertiliser F+N30 – 8.88 ± 0.08%, whereas the lowest ash content in RCG was with fertiliser F + N150(75 + 75) – 7.02 ± 0.10 %, and in tall fescue with fertiliser F + N180(90 + 90) – 7.93 ± 0.13 %.

Application of vermicompost on RCG and tall fescue led to the lowest ash content 7.73 ± 0.10% in RCG and 8.83 ± 0.06% in tall fescue. To find out the correlation between ash content in grass plant biomass and N fertiliser, a correlation analysis was carried out (Fig. 2 and Fig. 3).

![Figure 1. Ash content in reed canary grass and tall fescue depending on fertiliser type and norm](image)

In this case there is close, negative linear correlation (r = -0.91, p < 0.05) between the RCG biomass ash content and N amount in fertiliser. As N dose is increased, ash content in biomass reduces; thus higher the N content in fertiliser, the lower ash content in slag.

![Figure 2. Average ash content in RCG biomass depending on N fertiliser norm](image)

\[ y = -0.0094x + 8.8211 \]

\[ R^2 = 0.8223, r = -0.91 \]
Figure 3. Average ash content in tall fescue biomass depending in N fertiliser norm

There is close, negative linear correlation between the tall fescue biomass ash content and N fertiliser norm ($r = -0.78$, $p < 0.05$); thus as N content in tall fescue biomass grows, the ash content decreases.

The lowest ash content was observed for RCG samples treated with vermicompost (7.73 ± 0.10%). Notably higher ash content ($p < 0.05$) was recorded when samples were not treated with fertilisers (8.24 ± 0.06%); while application of fertilisers leads to ash content 7.98 ± 0.17% that does not notably differ from ash content in RCG samples grown in soil fertilised with vermicompost, as well as from RCG samples not treated.

Figure 4. Comparison between average ash content and fertiliser types in grass plant biomass

An opposite trend may be observed in tall fescue samples: highest ash content was recorded in samples treated with vermicompost (8.83 ± 0.06%), notably lower ($p < 0.05$) in samples not treated and treated with N (8.41 ± 0.01% and 8.42 ± 0.10%, respectively).

Thus it may be concluded that use of fertilisers did not leave notable influence on the ash content in biomass of both grasses.

Conclusions

The data acquired show that biomass of both reed canary grass and tall fescue has high ash content, therefore it would be useful to produce pellets from grass plant biomass mixed with wood, since it would reduce ash content.

Analysis of the information obtained shows the lowest ash content in grass plant biomass treated with vermicompost, moreover in reed canary grass samples it was lower, as compared to tall fescue.

Research indicated close, negative linear correlation between the grass plant biomass ash content and nitrogen fertiliser norms. Thus higher nitrogen norms reduce the ash content in grass plant biomass, meaning that use of N to increase the yield will not influence ash content.

Research allows concluding that application of fertilisers does not leave significant influence on ash content.

Acknowledgements. The research was supported by the European Regional Development Fund, Agreement No. 2010/0320/2DP/2.1.1.1.0/10/APIA/VIAA/107.

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References


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Impact of Sustainable Tillage and Sowing Machinery on Soil Physical Properties, Winter Wheat Crop Development and Productivity in On-Farm Scale Experiments

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Aleksandras Stulginskis University, Lithuania

Abstract
Short-term on-farm scale field experiments were carried out in 2011-2012 in three different regions of Lithuania: Vilkaviskis (Central part of Lithuania), Pakruojis (Northern part) and Klaipeda (Western part). The soil of Vilkaviskis region was light silty loam, in Pakruojis region – sandy light loam and in Klaipeda region – sandy heavy loam. The aim of investigations was to establish the influence of sustainable soil tillage and continuous sowing on soil physical properties, winter wheat crop development and productivity in different regions of Lithuania. Soil was tilled with combination of Agrisem subsoiler (Cultiplow 52, up to 40 cm depth) and disc harrow (Combinilch, up to 5-8 cm depth). Winter wheat was sowed with Agrisem drill DISC-O-SEM-DS610-SUPER in continuous (scattered) manner. Results of investigations showed that applying of the subsoiling + disking (twice) combination warranted favourable soil physical properties for winter wheat development in different conditions of microclimate and soil texture. After winter wheat sowing and after wintering capacity of water stable soil aggregates was higher than 50%, soil bulk density and penetration resistance mostly did not reach limitary conditions (1.4 g cm$^{-3}$ and 2.0 MPa). At the renewal of winter wheat vegetation in all experimental sites penetration resistance of top layers (up to 20-25 cm depth) was higher than after sowing. However, in spring in deeper soil layers soil penetration resistance decreased. That depended on higher soil moisture content and subsoiling impact. Despite of high coverage (61-74%) of soil surface by the oilseed rape residues, continuous sowing machine formed sufficient winter wheat crop density and led to rapid crop development and plenty (up to 9.05 t ha$^{-1}$) yield of grain.

Key words: sustainable tillage, subsoiling, continuous sowing, winter wheat, soil physical properties, development, productivity.

Introduction
The newest sustainable tillage and sowing technologies protect environment, set by labour input and decrease fuel consumption, preserve soil erosion, keep soil water, optimize tillage and sowing operations and, finally, may lead less costs of the agricultural production (Šarauskis and Špokas, 2002; Šarauskis et al., 2005; Romaneckas et al., 2011). Worldwide development of sustainable soil tillage and sowing technologies in agriculture became faster and faster. Since 1989 crop sowing to minimally tilled or non-tilled soil area increased about 13 times (Šarauskis et al., 2009) and non-tillage was applied in 117 million hectares (Lopez et al., 2012).

Changes in soil tillage intensity mostly influence on soil bulk density, compaction, water content and regime, structural composition and stability (Buragione et al., 2011; Rusu et al., 2011; Kumar et al., 2012). Non-tillage or sustainable (reduced) soil tillage often increase soil bulk density and stability of structure (Feiza et al., 2006), penetration resistance (Alvarez and Steinbach, 2009), water content (Feizienė et al., 2009; Romaneckas et al., 2013) and decrease the quantity of soil silty aggregates of the top soil layers (Bogužas et al., 2010; Romaneckas et al., 2012).

How much the sustainable soil tillage influences on wheat productivity? In arid climate conditions tillage with chisel plough + disking and no-tillage improved water storage in the soil and that increased yield of wheat grain by the 25-42%. Tillage methods did not have significant effect on mass of 1000 kernels (Hammat and Eskandari, 2006). Similarly, in conditions of annual rate of precipitations up to 42 mm different tillage systems did not affect winter wheat yields (Halvorson et al., 2002).

In semi humid climate conditions the yield of winter wheat was not very different between reduced and conventional tillage systems (Šip et al., 2009). In irrigated fields reduced tillage mostly led higher yields of wheat in comparison with conventional tillage because of lowered ratio of evaporation to water consumption under reduced tillage. The most effective was irrigation rate by 660 mm (90% of the traditional irrigation amount) (Fan et al., 2013), which was very close to the annual precipitation rate in the Central Lithuania.

Reduction of soil tillage intensity requires special sowing equipment because of higher soil compaction and amount of crop residues on soil surface (Šarauskis et al., 2013a; Šarauskis et al., 2013b). One of the ways how to prevent negative influence of plant residues is the continuous sowing without any sowing shares. However, seeds might be incorporated uneven – 20-40% of seeds remain on soil surface, and field germination reaches only 60-72% (Kraujalis, 2001).

Sustainable soil tillage in combination with subsoiling and continuous sowing (free seed distribution) are not widely investigated by Lithuanian scientists and adapted in the farms. So, we need to answer, what influence of such technologies on soil physical properties, winter wheat germination, crop development and productivity is.

Materials and Methods

Site, soil and experiment description. Short-term on-farm scale field experiments were carried out in 2011-2012 in three different regions of Lithuania: Vilkaviskis (Central part of Lithuania), Pakruojis (Northern part) and Klaipeda (Western part). The soil of Vilkaviskis region was light silty loam (sand 10%, silt 65%, clay 15%), in Pakruojis region – sandy light loam (sand 62%, silt 31%, clay 7%) and in Klaipeda region – sandy heavy loam (sand 48%, silt 21%,...
clay 31%). The amount of humus was 1.5–2.0%. The experimental fields were not less than 3 hectares each; the design was split-plot. The pre-crop of winter wheat was winter oilseed rape (Table 1).

<table>
<thead>
<tr>
<th>Experimental site</th>
<th>Height of straw cm</th>
<th>Soil surface coverage %</th>
<th>Weediness units m⁻²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vilkaviskis region</td>
<td>26</td>
<td>61</td>
<td>50.3</td>
</tr>
<tr>
<td>Pakruojis region</td>
<td>23</td>
<td>66</td>
<td>79.6</td>
</tr>
<tr>
<td>Klaipeda region</td>
<td>21</td>
<td>74</td>
<td>85.4</td>
</tr>
</tbody>
</table>

Soil was tilled with combination of Agrisem subsoiler (Cultiplow 52) and disc harrow (Combimulch). Winter wheat was sowed with Agrisem drill DISC-O-SEM-DS610-SUPER. Technological aspects of experiment are presented in Table 2.

<table>
<thead>
<tr>
<th>Technological operation</th>
<th>Timing of technological operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Use of combined implement: subsoiling (up to 40 cm depth) + disc harrowing (up to 5-8 cm depth)</td>
<td>After pre-crop harvesting</td>
</tr>
<tr>
<td>Fertilization (NPK 8:20:30, 150 kg ha⁻¹)</td>
<td>After primary soil tillage</td>
</tr>
<tr>
<td>Use of combined implement again</td>
<td>Two weeks after primary soil tillage, after sprouting of weeds and loss of oilseed rape</td>
</tr>
<tr>
<td>Continuous sowing (sowing rate – 200 kg ha⁻¹ of seeds, sowing depth – 3-5 cm, sowing speed – up to 22-24 km h⁻¹, variety “Olivin”)</td>
<td>Directly after last straw loosening, beginning of September</td>
</tr>
<tr>
<td>Fertilization (Nₘᵢᵦ, ammonium nitrate, 200 kg ha⁻¹ + NPK 8:20:30, 200 kg ha⁻¹)</td>
<td>After wintering, April</td>
</tr>
<tr>
<td>Spraying with growth regulators (Kemira CCC, 1.0 l ha⁻¹)</td>
<td>Tillering – stem elongation</td>
</tr>
<tr>
<td>Spraying with herbicides (Granstar 0.008 kg ha⁻¹ + Primus 0.07 l ha⁻¹ + Kemwett S 0.1 l/ ha⁻¹)</td>
<td>Spring, at wheat tillering time</td>
</tr>
<tr>
<td>Fertilization (Nₘᵢᵦ, ammonium nitrate, 100 kg ha⁻¹)</td>
<td>Boot stage</td>
</tr>
<tr>
<td>Spraying with fungicides (Bumper, 0.5 l ha⁻¹)</td>
<td>Booting-flowering</td>
</tr>
<tr>
<td>Spraying with insecticides (Fastac, 0.2 l ha⁻¹)</td>
<td>During insect invasion</td>
</tr>
<tr>
<td>Spraying with fungicides (Opera, 0.75 l ha⁻¹)</td>
<td>Up to the end of heading</td>
</tr>
<tr>
<td>Harvesting</td>
<td>Hard dough ripening</td>
</tr>
</tbody>
</table>

Methods. Soil texture was established by USDA triangle method (Motuzas et al., 2009 according to the Grybauskas and Juodis (1998) modification). Soil structural composition and its stretch were investigated by N. Savinov method of dry and vet sieving (Nerpin and Chudnovski, 1967; Revut, 1972) at 5 separate places per each experimental field. Sampling depth was 0-25 cm. For dry sieving we used sieves with 10, 7, 5, 3, 2, 1, 0.5 and 0.25 mm perforations and for wet – with 5-0.25 mm. Soil moisture (gravimetric moisture content) and soil bulk density were measured by cylindrical method (Vadiunina and Karchagina, 1983). Capacity of cylinders was 200 cm³. Samples were dried in 105 °C temperature till mass of cylinders became stable. Soil penetration resistance was evaluated by using an “Eijkelkamp” penetrometer 06.15 SA up to a depth of 50 cm. Five measurements per plot were performed for modeling of the composite curve. Winter wheat development stages were evaluated according to the BBCH scale (Meier, 2001). Winter wheat crop density and productivity parameters were established with the 20x30 cm size frame in no less than 16-20 places of each experiment. Mass of 1000 grain was evaluated by counting method. Three samples were counted per each specimen.

Meteorological conditions. In Lithuania August is the most arid summer month. Cereal harvesting starts this month. However, in 2011 August was humid, warm and disturbed harvesting and soil tillage operations (Fig. 1). It rained 21 days in Klaipeda, 20 days in Kybartai and 17 in Siauliai regions. In September average air temperature varied from 11 to 18 °C, but precipitation rate stilled surplus, especially in Klaipeda region. During 17 rainy days precipitation rate reached 106.4 mm and disturbed harvesting, soil tillage and sowing works.
2011/2012 winter conditions were favourable for winter wheat, except in Klaipeda region because of higher rate of precipitations. Some fields were flooded by surplus water. In our experiment subsoiling prevented such problem and wintering was respectable. Spring weather conditions were optimal for winter wheat development. However, in June and July storms and showers laid crops. In our experimental fields winter wheat was sowed in continuous manner and damages were less than in other fields because of more even plant distribution. At that time warm and humid weather raised plant diseases, ripening was uneven. Despite that the yield of grain was plenty and reached 5.5-9.0 t ha⁻¹.

Results of research

In 2011 autumn after subsoiling, straw loosening, fertilization and sowing operations the soil structure consisted higher amount of megastructure and less – silty microstructure (Table 3). Capacity of water stable soil aggregates was higher than 50%. In top soil layer (0-10 cm) soil bulk density did not reach limitary conditions (1.4 g cm⁻³), similarly with penetration resistance (2.0 MPa) (Fig. 2). Moisture content depended on precipitation rate; however, it was sufficient for seed germination and development of sprouts in each experimental site. Under those conditions winter wheat formed even and optimally dense crop (Maiksteniene et al., 2006) (Table 4).

Table 3. Change of soil structure, moisture content and bulk density during wheat wintering

<table>
<thead>
<tr>
<th>Experimental site</th>
<th>Structural composition %</th>
<th>Strength of structure %</th>
<th>Moisture content (0-5 cm) %</th>
<th>Moisture content (0-10 cm) %</th>
<th>Soil bulk density (0-10 cm) g cm⁻³</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mega- &gt;10 mm</td>
<td>macro- 1-10 mm</td>
<td>mezzo- 3-5 mm</td>
<td>micro- &lt;0.25 mm</td>
<td>Vilkaviskis region 69.0</td>
</tr>
<tr>
<td></td>
<td>40.5</td>
<td>57.0</td>
<td>14.2</td>
<td>2.5</td>
<td>Pakruojis region 72.2</td>
</tr>
<tr>
<td></td>
<td>45.4</td>
<td>52.6</td>
<td>12.9</td>
<td>2.0</td>
<td>Klaipeda region 58.3</td>
</tr>
<tr>
<td></td>
<td>31.2</td>
<td>64.2</td>
<td>14.1</td>
<td>4.6</td>
<td></td>
</tr>
</tbody>
</table>

Note: in numerator – soil physical properties after winter wheat germination (10-14 10 2011), in denominator – after wintering (08-15 05 2012).
After crop wintering soil structural composition changed. There were observed less amount of megastructure and higher capacity of agronomically valuable mezzostructure and strength of structure. Moisture content at different soil layers was sufficient and reached 14.6-20.1%. Soil bulk density stilled proper for wheat development, despite higher precipitation rate in winter time (Table 3). In all experimental sites penetration resistance of top layers (up to 20-25 cm) was higher than before wintering (Fig. 2). However, in spring we observed decrease of soil compaction in deeper soil layers. That depended on higher soil moisture content and subsoiling impact. In autumn we did not observe positive effect of subsoiling on soil penetration resistance of deeper layers because of continuous passes with heavy vehicles during loosening, fertilizing and sowing. Such conditions of soil positively influenced on winter wheat tillering (Table 4).

Figure 2. Change of soil penetration resistance before and after wintering wheat wintering

According to the Busscher et al. (2000) experiments, every megapascal decrease in mean profile cone index increased wheat yields 1.5–1.7 Mg ha\(^{-1}\). Similarly, in our experiment subsoiling of deeper soil layers (35–40 cm) decreased soil penetration resistance by about 1.0–2.5 MPa. That optimized water regime in the soil improved winter wheat development.

Table 4. Winter wheat crop development and productivity

<table>
<thead>
<tr>
<th>Experimental site</th>
<th>Total number of stems m(^{-2}) before wintering</th>
<th>Total number of stems m(^{-2}) after wintering</th>
<th>Total number of productive stems m(^{-2}) before harvesting</th>
<th>Number of productive stems m(^{-2})</th>
<th>Yield of grain t ha(^{-1})</th>
<th>Mass of 1000 grain g</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vilkaviskis region</td>
<td>308.2</td>
<td>577.8</td>
<td>587.5</td>
<td>583.3</td>
<td>9.05</td>
<td>53.10</td>
</tr>
<tr>
<td>Pakruojis region</td>
<td>445.8</td>
<td>747.2</td>
<td>595.8</td>
<td>595.8</td>
<td>6.01</td>
<td>40.34</td>
</tr>
<tr>
<td>Klaipeda region</td>
<td>350.4</td>
<td>496.7</td>
<td>450.0</td>
<td>446.2</td>
<td>5.58</td>
<td>46.87</td>
</tr>
</tbody>
</table>
In our previous investigations higher coverage of soil surface with oilseed rape plant residues influenced on sowing quality decrease. That mostly affected significantly lower winter wheat seed germination and formation of productive stems (Romaneckas et. al., 2012). In presented experiments residues of winter wheat pre-crop (winter oilseed rape) covered 61–74% of soil surface and at the beginning of vegetation density of winter wheat crop was little less than optimal, but after wintering wheat crop became of proper density (Table 4). Kraujalis (2001) observed similar results in continuous sowing experiments. In Klaipeda region winter wheat seed germination was higher than in other experimental sites, however higher precipitation rate and frequent snow breaks in winter time disturbed crop development and decreased productivity of wheat. Ghuman et al. (2001) found that in humid vegetation conditions (annual rate of precipitation – more than 1000 mm) grain yield in minimum tillage treatment was lower than in conventional tillage. We had similar conditions – annual precipitation rate in Klaipeda was about 960 mm (Fig. 2). In Pakruojis region the winter wheat formed denser crop than in other regions. However, some stems were damaged by storm, shower and spread of leaf diseases during vegetation. In such conditions mass of grains was less than in other sites (Table 4).

Conclusions

Practice of the subsoiling + disking (twice) combination warranted favourable soil physical properties for winter wheat development in different conditions of microclimate and soil texture. After winter wheat sowing and after wintering capacity of water stable soil aggregates was higher than 50%, soil bulk density and penetration resistance mostly did not reach limitary conditions (1.4 g cm\(^{-3}\) and 2.0 MPa). At the renewal of winter wheat vegetation in all experimental sites penetration resistance of top layers (up to 20–25 cm depth) was higher than after sowing. However, in spring in deeper soil layers soil penetration resistance decreased. That depended on higher soil moisture content and subsoiling impact.

Despite of high coverage (61–74%) of soil surface by the oilseed rape residues, continuous sowing machine formed sufficient winter wheat crop density and warranted plenty (up to 9.05 t ha\(^{-1}\)) yield of grain.

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References


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The Weight Ratio and Calorific Value Analysis of Subcomponents of the Jatropha Curcas Seed

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² Czech University of Life Sciences in Prague

Abstract

Sustainability in the energy consumption area is inextricably linked with the search of new alternatives. From the ecological point of view vegetable oil-based biofuels are in many aspects better than fossil fuels. The aim of the research is analysis of Jatropha curcas seeds in terms of weight ratio of the subcomponents, as a seed coat, seed kernel. Another aim is to determine the calorific value of these components and compare this value with the calorific value of pressed oil.

It was determined that the kernel of Jatropha curcas is 62.7% and seed coat is 37.3%. The average unit weight of the seeds was 0.64 ± 0.11 g, of the seed kernel was 0.40 ± 0.09 and seed coat was 0.24 ± 0.03 g. In the light of statistic by Tukey HSD test there is not homogeneity between the tested calorific value and inconsumable residue series. The calorific value is of 36.7% lower in the case of energy utilization of the seed (i.e. seed kernel with seed coat) against to oil obtained by pressing.

Introduction

Sustainability in the energy consumption area is inextricably linked with the search of new alternatives. It is one of the options that is currently preferred by the “green energy”, "renewable energy sources" and others. The reason is the limited amount of fossil fuels. Another problem is the use of petroleum derivatives in the production area of polymeric materials. The availability of petroleum is limited due to the dynamical increase of energy consumption. There are also many possible alternatives in this area. The major alternatives include recycling process, as a mixed plastics (Müller, Valasek, 2011) and elastomer granules.

From the ecological point of view vegetable oil-based biofuels are in many aspects better than fossil fuels, such as in the agricultural machinery area (Pexa et. al., 2013; Ales et. al., 2012).

According to the requirements for biofuels and yield production tropical plant berries from the countries in the tropical zone are particularly suitable.

In the tropical belt countries are there several dozens of prospective oleiferous plants as oil palm, coconut, cotton, soya, Jatropha curcas and others. A significant percentage of oil of these plants crops is used in the food-industry. Currently the Jatropha curcas oil is not used in the food-processing industry. Although, there is effort in the improvement area to remove this limits. The Jatropha curcas oil is used for several centuries as a fuel and it is also used in the pharmaceutical industry (Kabutey et al., 2011; Herák et al., 2013).

One of the world's largest producers of energy crops is Indonesia. Geographical and climate conditions in this area make possible to grow these crops without seasonal breaks.

In terms of analysis Jatropha curcas is one of the prospective crop in the area of tropical and subtropical belt (Herák et al., 2013; Petrů et al., 2012). The products obtained from the processing of Jatropha curcas have been traditionally used in various industries - energetics, pharmaceutics, cosmetics, natural fertilizers, etc.).

The basic technologic process to obtain the oil from crops is pressing. Pressing is a complex process and a number of authors deal with this process in the papers. Detailed understanding of the process of oil pressing is important factor that can help to find the system with maximum ratio of energy: output versus input (Herák et al., 2013; Kabutey et al., 2012; Petrů et al., 2012).

In a detail focusing on the process of pressing it is possible to find that simple pressing model ignores the phase change of mixture and during the compression oil is extracted and air is compressed. The air is contained among the components of the seed. In real pressing there is oil and air extracted cross the perforation in the walls of tank that is a merit how can be oil obtained. However, the volume of extracted oil is influenced by species and varieties of the plant, previous crop, soil and climatic conditions and agrotechnical process (Herák et al., 2013; Uličný et al., 2013).

The aim of the research is the analysis of Jatropha curcas seeds in terms of weight ratio of the subcomponents, as a seed coat, seed kernel. Another aim is to determine the calorific value of these components and compare the values with the calorific values of pressed oil.

Object and research methods

Calorific value evaluation of Jatropha curcas was performed with the brown coloured seeds that are overripe (Fig. 1). In the measurements there were used the samples of seeds that were crushed. In the industrial production of the oil whole seeds are pressed, however there are processes in which only kernels are pressed. Due to there is a need to determine the possible utility of the other seed subcomponents. The calorific value were measured for seed coat, seed kernel, whole seed (kernel with seed coat) and unrefined seed oil (Fig. 2 and 3). The refining is a cleaning process during which undesirable ingredients from the oil are removed. Before the evaluation process of calorific value there were determined the shares of the individual seed parts, as seed, seed coat and seed kernel.

Individual parts of the seed were separated mechanically by hand and with using a special knife. Emphasis was placed on minimal contamination of the parts.

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The basic instrument to evaluate the calorific value of each variant of the experiment was calorimeter PARR 6200 and digital scales for accurate laboratory weighing.

Individual prepared tested variants of experiments were mechanically crushed. To evaluate the calorific value for each variations of the experiment material was prepared and weighed at intervals of 1 to 3 grams. The spacemen was inserted into the test container where was placed the wick (the wick is to ignite the spacemen). Than the container was closed and there was created air overpressure which is necessary for combustion process. The second container was filled with two litres of distilled water, which is used for cooling. The container with the spacemen was placed into the container with distilled water and subsequently was placed into the test area of calorimeter. The container shell (located test spacemen) is measured by sensors and another sensor measures the water temperature depending on time.

Figure 5. *Jatropha curcas* seed with coat

Figure 6. *Jatropha curcas* seed kernel

Figure 7. *Jatropha curcas* seed coat
Results of Research

The results of experiments that were aimed to determine the weight ratio of the individual components, it means seed coat and seed kernel can be seen in the Figure 4 below. To determine the variation in weight of 120 tested seeds and respective amount of the seed coat and seed kernel coefficient of variation was used. The coefficient of variation is defined as a ratio of the standard deviation and the arithmetical average, in the case of seed kernel the value was determined 22.4%, for seed coat 11.4% and the whole seed 16.6%.

Proportion of the seed kernel is 62.7% and of the seed coat 37.3%. The average weight of the seeds was 0.64 ± 0.11 g, in the case of kernel it was 0.40 ± 0.09 g and seed coat 0.24 ± 0.03 g. Sirisomboon et al. (2007) found out different results. They determined the proportion of seeds kernel to 52% and seeds coat to 48%.

![Figure 8. Graph-box showing results of percentage by weight of Jatropha curcas seed, kernel and seed coat](image)

Graphical exemplification of the calorific value results of Jatropha curcas subcomponents was prepared by ANOVA with method of least squares (MLS) as can be seen in Figure 5. The Tukey’s HSD test was used for the statistical comparison of mean values. In the Table 1, there is shown single means in the statistically homogeneous groups.

The difference among the tested series is clear in the comparing of the average data set values of calorific value and inconsumable residues. In the light of statistic there is not homogeneity among the tested series. The calorific value of the oil from Jatropha curcas is higher than in the case of natural gas. The calorific value of the seed coat exceeded the calorific value of wood (17 MJ/Kg).

![Figure 9. Calorific value of particular Jatropha curcas product](image)
Table 4. Statistical comparison of mean values - Tukey's HSD test

<table>
<thead>
<tr>
<th>Designation</th>
<th>Calorific value</th>
<th>Agreement</th>
<th>Inconsumable residues</th>
<th>Agreement</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MJ/kg</td>
<td>1 2 3 4</td>
<td>g</td>
<td>1 2 3 4</td>
</tr>
<tr>
<td>Seed coat</td>
<td>18.21</td>
<td>*</td>
<td>0.00</td>
<td>*</td>
</tr>
<tr>
<td>Seed with coat</td>
<td>24.88</td>
<td>*</td>
<td>0.60</td>
<td>*</td>
</tr>
<tr>
<td>Seed kernel</td>
<td>29.27</td>
<td>*</td>
<td>1.00</td>
<td>*</td>
</tr>
<tr>
<td>Unrefined oil</td>
<td>39.32</td>
<td>*</td>
<td>1.46</td>
<td>*</td>
</tr>
</tbody>
</table>

Conclusion

In recent years biofuels have obtained considerable interest, due to the implementation of ruling and gradual replacement of fossil fuels. World research is focused mainly on searching of new and effective sources of biofuels. Potential place to obtain these biofuels is primarily in tropical and subtropical areas where are facilities for the harvest a few times per year and yield maximization. However in these areas there is problematic infrastructure and availability of efficient technologies very often event.

In this paper *Jatropha curcas* seed is analysed from the view of the volume and calorific value of the subcomponents. Absence of the consensus is obvious from the statistical evaluation of homogeneity of the calorific value. From the calorific value point of view the highest values in the test are reached according to an assumption at the oil. The calorific value is of 36.7% lower in the case of energy utilization of the seed with seed coat against to oil obtained by pressing.

References


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Research of Different Concrete Shrinkage Reducing Strategies Effectiveness

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Abstract

Concrete and reinforced concrete is one of the most widely used construction material in hydraulic, civil, and transport engineering structures. These structures constantly exposed to aggressive environment like fluctuation of water levels, water pressure, cold, solar radiation, wind, ice. Therefore, concrete and reinforced concrete structures must have special durability, safety and longevity to avoid various accidents and failures, which have a negative effect to environment. In order to ensure the environmental safety many strategies are used.

One of the problem causing concrete and reinforced concrete deterioration is shrinkage, which cause internal structural defects and cracking.

Shrinkage of concrete is the time-dependent decrease in concrete volume. It can be considered as a complex physical phenomenon that involves several processes: formation of structure due to cement hydration, variation of physical–mechanical properties with time, and moisture transportation followed by the changes in its content. The four main sources of such deformations are plastic, autogenous, carbonation, and drying shrinkage.

(1) Plastic shrinkage is associated with moisture loss from fresh concrete into the surrounding environment.
(2) Autogenous deformation is quite early shrinkage of concrete caused by loss of water from capillary pores due to the hydration (without the environmental loss of water). It tends to increase at lower values of water-to-cement (W/C) ratio or at a higher cement contents. Autogenous shrinkage occurs primarily as a result of chemical processes (volume reduction due to the hydration) and self-desiccation (internal consumption of water) in concretes made significantly reducing the water demands (0.2 < W/C < 0.42).
(3) Carbonation shrinkage is caused by the chemical reactions of various cement hydration products with carbon dioxide present in the environment.
(4) Drying shrinkage is the volumetric change due to the moisture losses in the hardened concrete. Drying shrinkage is caused by the movement and the loss of water squeezing out from the pores due to decreased the capillary pressure since the internal humidity attempts to make uniform with an environmental conditions. Due to rapid loss of the water in thinner structures (with higher surface area to volume ratio), the drying shrinkage might become the most significant among the above components (Gribniak et al, 2013).

Shrinkage of concrete takes place in two distinct stages: early and later ages. The early stage is commonly defined as the first day, while the concrete is setting and starting to harden. A later age, or long term, refers to the concrete at an age of 24 h and beyond. Within each of these two stages of shrinkage, there are also various types of linear change which can be physically measured on a specimen, mainly drying and autogenous. Both of these types can occur during either shrinkage stage. Overall, the early-age autogenous and chemical shrinkages are not equivalent during the first 24 h due to many factors. There are differences in the two types of shrinkages, such as bleed water, thermal dilation, strength development (setting), and restraint provided by aggregates. Some of the measures that can be taken to reduce the risk of early-age autogenous shrinkage are to:
- lower the chemical shrinkage by selecting cements with a low C3A and high C2S content,
- lower the rate of chemical shrinkage by selecting coarser ground or slow reacting cements,
- limit the chemical shrinkage by using the minimum amount (or no) superplasticizer, because these chemicals improve cement dispersion and accelerate chemical shrinkage,
- encourage a coarser pore structure (i.e., high w/c ratio, limited or no silica fume, etc.) to minimize the amount of early-age capillary pressure,
- accelerate the setting time so the concrete is stiff enough to resist shrink stresses,
- accept some bleed water, because it acts as a self-curing blanket and prevents autogenous shrinkage,
- use higher amounts of coarse aggregate to provide restraint to shrinking paste (Holt, 2005; Tongarooonsri et al., 2009).

In each case, a basic understanding of the underlying physical phenomena will aid the engineer in either selecting appropriate materials or adapting the structural design to control cracking due to autogenous shrinkage. Many
of the proposed mitigation strategies are still in their infancy and must yet be evaluated in terms of effectiveness, robustness, ease of implementation, and effects on durability. The tremendous need to produce crack-free concrete, however, will surely greatly expedite this evaluation process (Bentz et al., 2004).

One of the strategy to reduce shrinkage is concrete curing by water ponding, covering with wet burlap, or by the application of a curing compound. According to M. Maslehuddin, M. Ibrahim, M. Shameem, M.R. Ali, M.H. Al-Meththel research (2013) the plastic shrinkage strain in the concrete specimens cured by applying the selected curing compounds is less than that in the concrete specimens cured by covering with a plastic sheet. The lowest plastic shrinkage strain is in the concrete specimens on whom a bitumen-based curing compound applied. This indicates that curing compounds provide better resistance to water evaporation compared to the plastic sheet.

Next strategy to reduce shrinkage is to use special admixtures and additives. M. S. Meddah, M. Suzuki, R. Sato (2011) research confirmed that the addition of an appropriate amount of a combination of shrinkage reducing and expansive admixtures is very efficient to mitigate autogenous shrinkage strains and the internal self-tensile stress induced in high performance concrete with a w/c of 0.23 or higher. As a result, such a concrete can advantageously be used in reinforced concrete structures without any wet curing. The similar conclusions about shrinkage reducing and expansive admixtures effect to reduce shrinkage get V. Corinaldesi (2012) too.

Fibres are highly effective in controlling plastic shrinkage cracking in concrete too. Many scientific works confirms that glass fibers (Messen et al., 2011), polypropylene fibers (Banthia, 2006; Filho et al., 1999; Passuello et al., 2009), PET fibers (Pelisser et al., 2010) and hybrid fibers (Sun et al., 2001) reduce the shrinkage. Wire mesh as cracking reducing way must not be forgotten (Soltani et al., 2003).

Reviewing the scientific works it was not determined which strategy and which material is most effective. Therefore, it is important to compare different strategies and materials for concrete shrinkage reduction during hardening process (28 days).

Materials

During the research four different materials of first strategie and one of second were used to reduce the shrinkage of concrete.

The first material (E) is dry powder expansive admixture, which together with clinker materials contained in cement forms reaction products with significantly increased volume, that compensates shrinkage of cement mortars and concretes generated because of their drying. The amount of admixtures was applied 5 % from cement mass (as recommended by manufacturer).

The second material (SRA) is liquid shrinkage reducing admixture, which reduce water vaporizing from cement mortar and concrete due to that admixture reduce the shrinkage deformations and cracking. The amount of admixtures was applied 2 % from cement mass (as recommended by manufacturer).

The third material (PPF) is polypropylene fibres designed to distribute quickly through the concrete matrix. This material is used in concrete products for the purpose of controlling plastic shrinkage and thermal cracking. The amount of fibres was applied 0.91 kg to 1 m³ of concrete (as recommended by manufacturer).

The fourth material (MSF) is monofilament macro synthetic fibres that are extruded and embossed. The embossment improves the bond within the concrete and so reduces pull-out and enhances the concrete's performance. The amount of fibres was applied 0.3 % from cement mass (as recommended by manufacturer).

The fifth material (P) is concrete curing material (base of paraffin) used to reduce water vaporizing from cement mortar and concrete. The surfaces of concrete specimens were slushed with this material after 24 hours from concrete mixing.

To have better effect and to estimate marked differences of different strategies on shrinkage reducing, the fine-grained concrete (aggregate fraction 0…4 mm) with ordinary cement CEM II/A-L 42,5 N was selected. The water-cement ratio was selected W/C = 0.5 as commonly used in practice for fine-grained concrete without plasticizers.

Aggregates and water used for concrete preparations meet the requirements described in European standards EN 12620:2002+A1:2008 and EN 1008:2002. For the test were used standard concrete samples (40×40×160 mm).

Test methods

The density and consistency of fresh concrete was estimated according to standard methods (EN 12350-6:2009 and EN 12350-5:2009). Flexure and compression strength, and water absorbability of hardened concrete were established according to standard methods (EN 196-1:2005, EN 13369:2004). The size of tested concrete specimens was 40×40×160 mm with the age of 28 days. Test of fresh and hardened concrete were applied to control concrete (C), concrete modified with expansive admixture (E), shrinkage reducing admixture (SRA), polypropylene fibres (PPF) and monofilament macro synthetic fibres (MSF).

To estimate the shrinkage deformations was used shrinkage meter. The shrinkage was measured every day over the 28 days. The test was estimated according to standard method (EN 12617-4:2002) in normal environmental conditions (temperature 18±5°C; relative humidity 65±10 %). Shrinkage test were applied to control concrete (C), concrete modified with expansive admixture (E), shrinkage reducing admixture (SRA), polypropylene fibres (PPF), monofilament macro synthetic fibres (MSF) and curing concrete (P) specimens. The effect of wire mesh on shrinkage in the research was not estimated.
Test results and discussion

The test results of fresh concrete show us (Table 1 and 2), that all materials had no influence to density of concrete mixture. The variation (1%) between results of different concretes is mostly connected with natural distribution of concrete density. Whereas, tested materials to another parameter (plasticity) had an effect. The highest effect had material E, which reduced the plasticity by 22% (estimated by flow table method) and reduced Flow class from F3 to F2. This effect can be explained, that expansive admixture was used in dry powder form and it absorbed part of the water, therefore the mixture was gained drier comparing with non-modified concrete mixture. Concrete admixture SRA increased the plasticity by 2% due to reducing water vaporizing features. This determined the increase of Flow class from F3 to F4. The last two materials PPF and MSF decreased the plasticity of concrete by 5 ÷ 6%. The reason of such effect is similar to material E, both materials were used dry and they absorbed part of water from the concrete.

Table 1. Test results of fresh concrete density

<table>
<thead>
<tr>
<th>Admixture/additive was used</th>
<th>Density of fresh concrete $\rho, kg / m^3$</th>
<th>Variation of fresh concrete density, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>2241</td>
<td>–</td>
</tr>
<tr>
<td>E</td>
<td>2233</td>
<td>– 0.4</td>
</tr>
<tr>
<td>SRA</td>
<td>2241</td>
<td>0</td>
</tr>
<tr>
<td>PPF</td>
<td>2219</td>
<td>– 1.0</td>
</tr>
<tr>
<td>MSF</td>
<td>2265</td>
<td>+ 1.1</td>
</tr>
</tbody>
</table>

+ show that value increased;
– show that value decreased.

Table 2. Flow table test results

<table>
<thead>
<tr>
<th>Admixture/additive was used</th>
<th>Flow, mm</th>
<th>Flowclass</th>
<th>Variation of flow of fresh concrete, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>481</td>
<td>F3</td>
<td>–</td>
</tr>
<tr>
<td>E</td>
<td>373</td>
<td>F2</td>
<td>– 22.4</td>
</tr>
<tr>
<td>SRA</td>
<td>492</td>
<td>F4</td>
<td>+ 2.3</td>
</tr>
<tr>
<td>PPF</td>
<td>457</td>
<td>F3</td>
<td>– 5.3</td>
</tr>
<tr>
<td>MSF</td>
<td>453</td>
<td>F3</td>
<td>– 5.8</td>
</tr>
</tbody>
</table>

+ show that value increased;
– show that value decreased.

Summarizing the results of fresh concrete it is important to state, that all materials have an effect to mixture plasticity. Therefore, using these materials it is necessary to correct (if needed) concrete composition for appropriate consistency of concrete.

The test results of hardened concrete (Table 3 and 4) show us that all materials have positive effect to concrete flexure and compression strength. The best effects to flexure strength have polypropylene (PPF) and monofilament macro synthetic (MSF) fibres. They increased the flexural strength by 35 and 14% respectively. This effect was influenced by reinforced structure of specimens. The compression strength all materials increased marginally by 4 ÷ 9%.

Table 3. Test results of flexure strength of hardened concrete

<table>
<thead>
<tr>
<th>Admixture/additive was used</th>
<th>Flexure strength, MPa</th>
<th>Variation of flexure strength, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>1.31</td>
<td>–</td>
</tr>
<tr>
<td>E</td>
<td>1.35</td>
<td>+ 3.0</td>
</tr>
<tr>
<td>SRA</td>
<td>1.39</td>
<td>+ 6.1</td>
</tr>
<tr>
<td>PPF</td>
<td>1.77</td>
<td>+ 35.1</td>
</tr>
<tr>
<td>MSF</td>
<td>1.49</td>
<td>+13.7</td>
</tr>
</tbody>
</table>

+ show that value increased;
– show that value decreased.

Table 4. Test results of compression strength of hardened concrete

<table>
<thead>
<tr>
<th>Admixture/additive was used</th>
<th>Compression strength, MPa</th>
<th>Variation of compression strength, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>22.6</td>
<td>–</td>
</tr>
<tr>
<td>E</td>
<td>24.5</td>
<td>+ 8.4</td>
</tr>
<tr>
<td>SRA</td>
<td>24.6</td>
<td>+ 8.8</td>
</tr>
<tr>
<td>PPF</td>
<td>23.6</td>
<td>+ 4.4</td>
</tr>
<tr>
<td>MSF</td>
<td>24.1</td>
<td>+ 6.6</td>
</tr>
</tbody>
</table>

+ show that value increased;
– show that value decreased.
Evaluating the effect on water absorbability of tested material it is possible to state that only expansive admixture (E) had a positive effect to this parameter of concrete and decreased it by 10%. Such effect can be explained that expansive admixture used same free water of concrete mixture, therefore concrete structure became less porous and capillary. Other materials (SRA, PPF and MSF) had no influence to water absorbability of concrete. The variation (> 4%) between results of different concretes is mostly connected with natural distribution.

Table 5. Test results of water absorbability of hardened concrete

<table>
<thead>
<tr>
<th>Admixture/additive was used</th>
<th>Water absorbability, %</th>
<th>Variation of water absorbability, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>8.39</td>
<td>–</td>
</tr>
<tr>
<td>E</td>
<td>7.57</td>
<td>– 9.8</td>
</tr>
<tr>
<td>SRA</td>
<td>8.71</td>
<td>+ 3.8</td>
</tr>
<tr>
<td>PPF</td>
<td>8.46</td>
<td>+ 0.8</td>
</tr>
<tr>
<td>MSF</td>
<td>8.58</td>
<td>+ 2.3</td>
</tr>
</tbody>
</table>

+ show that value increased; – show that value decreased.

The test results of shrinkage (Fig 1.) confirmed that autogenous and drying shrinkage most intensive in first 5 days after concrete mixing. The best results show shrinkage reducing admixture (SRA) which reduced shrinkage deformation of concrete by 29% comparing with non-modified concrete. Concrete curing material (P) reduced shrinkage deformation of concrete by 26% as well as expansive admixture (E) by 23% comparing with non-modified concrete. Polypropylene (PPF) and monofilament macro synthetic (MSF) fibres had the least influence to shrinkage deformation. These materials reduced shrinkage deformations by 8 and 16% respectively.

![Figure 1. Shrinkage of non-modified and modified concrete](image)

**Conclusions**

The highest effect on concrete mixture consistency had expansive admixture (E), which reduced the plasticity by 22%. Other materials: shrinkage reducing admixture (SRA), polypropylene (PPF) and monofilament macro synthetic (MSF) fibres changed the plasticity of concrete marginally up to 6%.

Estimated that all materials have positive effect to concrete flexure and compression strength. The best effects to flexure strength have polypropylene (PPF) and monofilament macro synthetic (MSF) fibres. They increased the flexural strength by 35 and 14% respectively.

The best results on shrinkage deformations show shrinkage reducing admixture (SRA), concrete curing material (P) and expansive admixture (E). These materials reduced shrinkage deformations by 29, 26 and 23% respectively. So these materials – SRA and E of first strategy and P of second strategy are the best choice avoiding cracks in concrete due to shrinkage. However, during further research it is possible to state the optimal amount of additives and admixtures, and estimate the effect of duplicated materials or strategies on shrinkage reduction.
References


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Effect of Magnetic Fields with Industrial Frequency on Water and Solution Properties

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Abstract

Water is an integral part of living organisms and it amounts to 80–90% of their weight. Water has many-sided significance on a cell. It acts as a solvent for mineral and for many organic materials, it is a medium for transportation of nutrients, were enzyme-catalysed metabolic reactions take place and chemical energy is transferred. Exposure to magnetic fields has changed water properties: polarized liquid structures are destroyed; changes occur in water, in ionic mobility of solutions and in intermolecular contacts, moistening and capillary properties of water (adhesion, cohesion) have been changed, as well as electrical conductivity, dielectric permittivity, magneto-optical characteristics and effect on biological objects. The article analyses effect of industrial frequency magnetic fields on moisturising properties of water and solution.

Analysis of the obtained results showed that dilatation area on filter paper and height of water in a capillary glass tube of magnetised water and solution depended on strength of magnetic field (H) and on speed of water and solution movement (v) through magnetising apparatus.

Key words: magnetic fields, magnetic field strength, power, velocity of water movement, dilatation area, capillary movement.

Introduction

The effect of magnetic fields on water was noticed even in XIII century for the first time. Even then this phenomenon, already known as magnetised water was used for medical purposes. In the beginning of XX century (in 1913) in a book published by G. Durville healing properties of magnetised water and its usage for medical purposes were widely described. In 1945 Belgian T. Vermeiren patented the application of magnetised water in heating power machinery as a measure against scaling.

Magnetic activation of running water with a permanent magnet increases viscosity and electric conductivity, reduces the electric-kinetic potential and accelerates heterogeneous ion-exchange processes in ion exchangers. These changes support hypothesis that magnetic activation decreases hydration of water-ion and the colloidal systems in water and therefore it accelerates coagulation of colloids, and ion diffusion into deeper layers of the granular ion exchangers in ion exchange filters. Method of intensification of industrial water treatment processes using magnetic activation in a permanent magnetic field is recommended, because it is an environment-friendly way, i.e. it does not require any additional amount of chemical materials (Mockutė, 2003).

Effect of magnetic fields on water results in variation of water properties, destruction of polarised liquid structures, changes in ion mobility in water and water solutions and in changes of intermolecular bonds (Klasscens, 1982; Chepuro, 1999). Exposure to constant and alternating magnetic fields affects Ca and Mg ionization in water (Stašelis, 2006). Alternating magnetic fields have influence on electric properties of water (Stašelis, 2004).

Effect of magnetic fields on water systems could be linked to resonance phenomenon. The effect of magnetic field of optimal frequency on the system results in emergence of quantum energy, with sufficient amount for deformation of bonds and the system structure. The main force in magnetic field, affecting movement of cations and anions is the Lorentz force (Klasscens, 1982).

Main factors that determine efficiency of magnetic field's influence on water and solution are strength of magnetic field (H), time of exposure to magnetic field (τ), velocity of water and solution flow (v) through magnetising apparatus. It is appropriate to use water treated in magnetic fields in different agricultural crops growing technologies; usage of magnetised water and solutions allows to optimise certain technological processes and to reduce environmental pollution (Stašelis, 1990; Stašelis, 1994; Грязнова, 1999, Chepuro, 1999, Курзин, 2004; Volkonsky, 1973).

Influence of magnetic fields on water solutions results in improvement of nutrient solubility and utilization in aggregates of soil particles, in increased cell membrane permeability and improved transport of substances towards roots. These changes are also associated with the transport of oxygen to ion systems of tissues, their connections with water and with variation of hydration degree (Пилюгина, 1979).

Objective of the study is: to explore influence of the industrial frequency magnetic fields on moisturising properties of water and solutions.

Materials and methods

We used the magnetising apparatus producing alternating magnetic fields (f = 50 Hz) and we had changed strength of magnetic field (H), velocity of water and solution movement (v) through the magnetising apparatus with water pump (Peristaltic miniflow pump type 304). Moisturizing properties of magnetised water and solution were explored using filtration paper and glass capillary tubes, 0,6 mm diameter. To determine water moisturizing properties, technical quality water was used K_B = 5.6 mgekv/l (2.8 mmol/l), pH=6. Water-based solution was produced according to Chesnakov and Bazirin methodology with the following composition (mg/I): N-140 (N-NH_2+-35; N-NO_3--105); P-90; K-190; Ca-170; Mg-30.

Each study variation had 4 repetitions. Moisturising properties of magnetised water solution and mean values of these parameters were determined applying Student's criterion. Magnetic field strength was measured with electric-
magnetic field meter HI – 3550 (Magnetic field Monitor), we used the device – Triaxial ELF Mikroteza Meter for magnetic flux density B (μT) measurement, its range was 20 Hz to 1000 Hz, the measuring error ± 2.0%.

Results of the research

Analysis of the obtained results showed that dilatation area on a filter paper (S) of magnetised water and solution depended on magnetic field strength (H) and on velocity of water and solution movement (v) through magnetising apparatus. Dependency of dilatation area of a droplet of magnetised water and solution on filter paper (S) (control) on the magnetic field strength (H) and on water and solution velocity through magnetising apparatus (v) is shown below, Fig. 1, 2, 3 and 4.

Figure 1. Dependency of dilatation area of a droplet on filter paper (S) on magnetic field strength (H) and on water and solution velocity (v)

Figure 2. Dependency of dilatation area of a droplet on filter paper (S) on magnetic field strength (H) and on water and solution velocity (v)
Figure 3. Dependency of dilatation area of a droplet on filter paper \( (S) \) on magnetic field strength \((H)\) and on water and solution velocity \((v)\)

Analysis of the results shows that the largest dilatation area of magnetised water droplet on filtration paper \( (S) \) was obtained, when water was exposed to magnetic field \((H = 96000 \text{ A} \cdot \text{m}^{-1}, S = 3.84 \text{ cm}^2)\); when solution was exposed to the field \((H = 114000 \text{ A} \cdot \text{m}^{-1}, S = 4.51 \text{ cm}^2)\) at water and solution velocity through the apparatus equal to \(v=0.6 \text{ m/s}\). At water and solution velocity through magnetising apparatus \(v = 0.8 \text{ m/s}\) and at \(H = 121500 \text{ A} \cdot \text{m}^{-1}\), the results were \(S = 3.80 \text{ cm}^2\) and for solution \(S = 4.54 \text{ cm}^2\).

In such conditions, when velocity of water and solution flow through magnetising apparatus reached to \(v = 1.00 \text{ m/s}\), at the magnetic field strength \(H = 121500 \text{ A} \cdot \text{m}^{-1}\), dilatation area of a magnetised water droplet was \(S = 4.03 \text{ cm}^2\) and for a solution \(S = 4.46 \text{ cm}^2\). Dilatation area of a droplet of water, not exposed to magnetising treatment \((S)\) (control) on filtration paper, was \(S = 2.82 \text{ cm}^2\) and for solution \(S = 3.01 \text{ cm}^2\). Dependency of height of magnetised water and water solution capillary rise \((h)\) in a glass capillary on magnetic field strength \((H)\) and on water and solution flow \((v)\) through magnetising apparatus is shown in Fig. 5, 6, 7 and 8.
Figure 5. Dependency of height of magnetised water and water solution capillary movement \( (h) \) in a glass capillary on magnetic field strength \( (H) \) and on water and solution velocity \( (v) \)

Figure 6. Dependency of height of magnetised water and solution capillary movement \( (h) \) in a glass capillary on magnetic field strength \( (H) \) and on water and solution velocity \( (v) \)

Figure 7. Dependency of height of magnetised water and solution capillary movement \( (h) \) in a glass capillary on magnetic field strength \( (H) \) and on water and solution velocity \( (v) \)
The highest capillary rise of magnetised water in a glass capillary \( h = 24.85 \) mm and for water solution \( h = 27.16 \) mm was determined at magnetic field strength level \( H = 114000 \, \text{A} \cdot \text{m}^{-1} \) and at water and solution velocity through magnetising apparatus \( v = 0.8 \) m/s. Once speed of water and solution flow had reached \( v = 1.0 \) m/s and at strength of magnetic field \( H = 121500 \, \text{A} \cdot \text{m}^{-1} \), height of water capillary movement was \( h = 24.81 \) mm and for a solution – \( h = 25.95 \) mm. Capillary rise of magnetised water in a glass capillary \( h = 24.73 \) mm (\( h = 25.53 \) mm for water solution) was determined at magnetic field strength \( H = 135000 \, \text{A} \cdot \text{m}^{-1}; v = 1.2 \) m/s. The height of capillary rise of water, not exposed to magnetic fields in a glass capillary \( h \) (control) was \( h = 22.05 \) mm and for \( h = 23.15 \) mm.

Conclusions

The results showed that the largest dilatation area of a magnetised water droplet on filtration paper \( S = 3.84 \) cm\(^2\) was obtained with water, exposed to magnetic field \( H = 96000 \, \text{A} \cdot \text{m}^{-1} \) and with solution, exposed to magnetic field \( H = 114000 \, \text{A} \cdot \text{m}^{-1} \); the largest dilatation area of magnetised water droplet \( S = 4.51 \) cm\(^2\) was at velocity of water and water solution flow through magnetising apparatus \( v = 0.6 \) m/s.

Dilatation area on filtration paper of water droplet without magnetic treatment was \( S = 2.82 \) cm\(^2\); for solution \( S = 3.01 \) cm\(^2\); height of capillary rise of water and solution without exposure to magnetic fields \( h \) in a glass capillary was \( h = 22.05 \) mm and for solution \( h = 23.15 \) mm.

The highest capillary rise of magnetised water \( h = 24.85 \) mm and solution \( h = 27.16 \) mm in a glass capillary was determined at strength of magnetic field \( H = 114000 \, \text{A} \cdot \text{m}^{-1} \) and at velocity of water and solution flow through magnetising apparatus \( v = 0.8 \) m/s.

Dilatation area on filter paper \( S \) and height of rise in a capillary glass tube \( h \) of magnetised water and its solution depends on strength of magnetic field \( H \) and on speed of water and solution movement \( v \) through magnetising apparatus.

It is appropriate to use water treated with magnetic fields in different growing technologies; usage of magnetised water and solutions allows to optimize certain processes and to reduce environmental pollution.

References

Substantiation of the Rational Technological Parameters for Threshing High-moisture Corn Ears

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Abstract

The article presents the results obtained during the research of harvesting mid-moisture corn ears Auxxel and high-moisture corn ears Lapriora (moisture level higher than 30%) using combine-harvester with axial threshing and separating rotor A, and with tangential threshing cylinder B. The rational technological parameters of threshing were justified by experimental research. It has been established, that when corn ears were fed to the threshing device A at the maximum feedrate of 24.8 kg s\(^{-1}\), total grain losses were 1.56 times lower compared to the grain losses of the combine-harvester B. The lowest grain damage rate was observed when corn ear feedrate was approximately 20 kg s\(^{-1}\). Upon increasing or decreasing the feedrate, corn damage rate increased. When threshing high-moisture corn ears, grain damage rate for the harvester A was higher by 0.67 percentage units compared to the harvester B. The maximum allowed peripheral velocity for the tangential threshing cylinder was 15 m s\(^{-1}\), while for axial rotor – 18 m s\(^{-1}\). Grain loss should be reduced not by increasing cylinder peripheral velocity but rather by altering the clearance between the cylinder (or rotor) rasp bars and the concave. In a tangential threshing device B, the clearance at the third concave bar must be in the interval 20–27 mm, which is approximately 22 mm smaller than average corn ear diameter. Combine-harvester operates efficiently when fuel consumption for threshing one tonne of grains is least, and grain loss does not exceed the permissible level. Using combine-harvester A and applying the rational feedrate of 20 kg s\(^{-1}\), hourly fuel consumption reached 90.5 litres, and threshing of one tonne of grains required 1.31 litres of fuel.

Key words: combine-harvester, corn ears, grain damage, grain losses, fuel consumption

Introduction

Corn, wheat and rice grains represent approximately 86% of all the grain produced in the world (Deutsches Maiskomitee e.V.). Corn grain is an important raw material for food and industrial production, and biomass silage is the main feed component for livestock. In the modern bio power plants, corn silage accounts for 90 percent of the total substrate used. In the world, corn is cultivated in the area of 169 million ha, while wheat – in the area of 223 mln. ha, however corn grain yield amount 865 mln. t while wheat yield is 1.25 times smaller. In the European Union countries (EU-27), maize is cultivated in the area of 8.5 million ha; grain yield from this area amounts to 66.6 million tones. In Lithuania, corn for grain was first planted in 2002. It used to be harvested using non-modified combine-harvesters leaving very high stubble. In 2011, corn cultivation areas for grain yields were 7.1 thousand ha, and average yield was 6.7 t ha\(^{-1}\). In large farms, average corn grain yield exceeded 10 t ha\(^{-1}\).

In Lithuania, at the end of October, meteorological conditions for corn harvesting are unfavourable, therefore the most suitable harvester for harvesting corn is combine-harvester with axial threshing-separating rotor or with tangential threshing device and rotary separators. For working in wet soil, harvesters with half-track chassis and drive axle are used. Instead of cutting table, harvester is attached a corn head, which cuts off corn ears from stems, and spreads the chopped stems on the stubble (Petkevičius et al., 2008b). Corn ears are threshed using tangential threshing devices with modified concave and with the gaps between the adjacent rasp bars of threshing cylinder covered, or using axial threshing-separating devices. In the cleaning shoe, upper sieve is replaced by long-scale sieve, while the lower sieve is replaced by flat sieve with 18 mm diameter sieve, or removed, and the tailing auger is covered. The rotation frequency of threshing cylinder, axial rotary separators, and straw chopper are decreased by increasing the velocity of grain auger and elevator.

In western countries, corn is harvested when moisture content of the grain is approximately 25% (Poničan et al., 2007). In Lithuania, early varieties of corn ears also manage to produce mature grains. Moisture content in these grains during harvesting reaches 35–40% (Bulgakov et al., 2006). Provided especially favourable meteorological conditions, moisture level in corn grains is reduced to 26–28%. The most important evaluation factors of combine-harvester operation when harvesting corn ears include grain loss, grain damage, work efficiency and fuel consumption (Rademacher, 2001). They are related to combine-harvester working conditions, technological parameters, and corn ear feedrate.

In tangential threshing device, corn ears are threshed with the help of rasp bar impact impulses the intensity of which depend on cylinder peripheral velocity. Grains are separated from ear pith with the help of rasp bar impulses the strength of which is higher than the contact force between grain and ear pith as well as adjacent grains (Petkevičius et al., 2012). The contact force between grain located at the end of ear and ear pith and the adjacent grain is 1.5 higher compared to the contact force at the top part of ear (Kravchenko and Molofeev, 1984). When force applied to grain makes up a 30° angle with its longitudinal axis, force of 17 N is enough for separation grain from pith. During threshing, some of corn ears are resting against concave bar for a short time. Grains are squeezed in the contact point of rasp bar and corn ear. It has been established that grains are separated from ear pith when they are pushed with 35 N radial or 29 N circumferential forces (Petunina, 2007). During threshing, some of corn ears get between rasp bar and concave bar. Since corn ear is cone-shaped, rasp bar pushes only a part of the grains of one corn ear. When rasp bar pushes grain towards pith for about 4–5 mm, the adjacent grains are separated from the pith (Petkevičius et al., 2008a).

During harvesting, threshing device is fed with corn ears of different diameters. The longitudinal axis may be perpendicular, parallel, or at an angle with concave bars. The position of corn ear also affects the indicators of threshing process (Piszczalka, 1997; Petkevičius et al., 2008a). Grain damage rate was 4.1% when corn ears were fed perpendicularly to the axis of threshing cylinder, and 5.2% when movement was chaotic (Piszczalka, 1997). Grain
damage depends on cylinder peripheral velocity and concave clearance. It has been established that grains start separating from pith when cylinder peripheral velocity is 7 m s\(^{-1}\) (Vindizhev, 1996). All grains are separated when the velocity of rasp bars is 10–20 m s\(^{-1}\) (Kutzbach and Quick, 1999). Rational concave clearance is 35–40 mm at the beginning and 18–20 mm at the end (Svoboda et al., 1990). When the cylinder peripheral velocity and concave clearance has not been set, corn ears are pushed along the concave surface two slowly or two quickly.

In an axial threshing device, it takes more time for corn ears to pass along the surface of the concave. Grains are separated from ear pith by compression, rubbing them in the clearance between rasp bars of the rotor and round rods of the concave. The impact of rasp bar impulses is smaller compared to the effect of tangential threshing cylinder rasp bars. It has been established that when increasing the velocity of threshing-separating rotor rasp bars from 16.9 m s\(^{-1}\) to 21.4 m s\(^{-1}\), grain damage increased by 0.7 percentage units, and having altered the clearance between rasp bars and the concave from 25 mm to 37 mm, damage reduced by 1.95 percentage units given the moisture level of the grains was 20% (Poničan et al., 2009). When threshing drier corn ears (grain moisture level 26%), grain damage increased to 3.8%.

In Lithuania, corn ears are harvested when grain moisture level is above 30%.

Laboratorially set rational technological parameters for threshing unit must be often adjusted subject to field conditions since threshing unit is supplied corn ears with not only different moisture level but also different stem parts and foliage. Moreover, in different field parts, the yield and maturity of crops differ. Environmental conditions demonstrate different impact on quality indicators of combine-harvesters with tangential threshing cylinder, and with axial threshing-separating rotor.

**Purpose of the study:** substantiation of rational technological parameters of a harvester with tangential threshing cylinder or axial threshing rotor when harvesting high-moisture corn ears.

**Subject of research:** two combine-harvesters with tangential threshing cylinder \(B\) and \(C\), and axial threshing-separating rotor \(A\); corn ears of different moisture level.

**Materials and methods**

**Meteorological conditions.** They are estimated according to the data of Kaunas Meteorological station.

**Combine-harvesters.** During the period of 2011–2012, harvesting of corn ears Auxxel and Lapriora by combine-harvester with axial threshing-separating rotor \(A\) and two combine-harvesters with tangential threshing cylinders and rotary separators \(B\) and \(C\) (Table 1) was researched under field conditions.

**Table 1. The most important technical data of combine-harvesters**

<table>
<thead>
<tr>
<th>Indices</th>
<th>Measuring units</th>
<th>(A)</th>
<th>(B)</th>
<th>(C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Header width</td>
<td>m</td>
<td>9.0</td>
<td>9.0</td>
<td>6.0</td>
</tr>
<tr>
<td>Cylinder (rotor) diameter</td>
<td>mm</td>
<td>762</td>
<td>600</td>
<td>600</td>
</tr>
<tr>
<td>Cylinder (rotor) length</td>
<td>mm</td>
<td>3124</td>
<td>1700</td>
<td>1700</td>
</tr>
<tr>
<td>Total separation area of concaves</td>
<td>m(^2)</td>
<td>3.1</td>
<td>1.26</td>
<td>1.26</td>
</tr>
<tr>
<td>Total separation area of sieves</td>
<td>m(^2)</td>
<td>4.9</td>
<td>6.2</td>
<td>5.8</td>
</tr>
<tr>
<td>Grain tank capacity</td>
<td>l</td>
<td>14100</td>
<td>12500</td>
<td>10500</td>
</tr>
<tr>
<td>Throughput of the grain auger</td>
<td>l s(^{-1})</td>
<td>135</td>
<td>130</td>
<td>110</td>
</tr>
<tr>
<td>Engine power</td>
<td>kW</td>
<td>405</td>
<td>370</td>
<td>340</td>
</tr>
</tbody>
</table>

The most important part of a combine-harvester is threshing-separating device. Threshing-separating device of combine-harvester \(A\) has three parts: feeding part, threshing part, and separator. The front (feed) part of the unit has the shape of a cone. Augers in the mentioned part of the unit create a uniform flow of corn ears to the threshing unit (threshing part), where there are rasp bars attached with the help of spiral lines, and four lines of teeth attached to cylindrical part (separator) of the unit in four lines. Every part of threshing-separating unit has casing of different diameter. Instead of traditional preparation pan, cleaning shoe has four augers that direct chaff-grain mixture to the air flow.

Threshing apparatus in combine-harvesters \(B\) and \(C\) is tangential. Before the main cylinder there is a crop accelerator 0.45 m in diameter, and behind the main cylinder there is a distribution drum which directs corn piths and a part of grains to two axial rotary separators with the diameters of 0.44 m and 4.2 m lengths. The velocity of rotors is being adjusted, and front concaves may be covered with special covers. The position of the concaves is controlled by hydraulic drive from the cabin. Combine-harvesters \(B\) and \(C\) have different tank capacities and engine power. Therefore, combine-harvester \(B\) was attached a 12-row corn head, while combine-harvester \(C\) – 8-row corn head.

**Corn ear biometrical indicators.** In the field selected for the research, distances between adjacent corn stalk rows were measured before harvesting. 50 corn ears were randomly collected. In a laboratory, corn ears were weighted and threshed manually calculating average weight of grain, piths, husks, and also the weight of 1000 grains, and average corn grain yield. Based on the width of combine-harvester corn head, combine-harvester travel speed, and the corn ear feedrate were calculated.
Determination of grain losses. During the research, different forward speeds of combine-harvester and corn ear feedrates were applied. After combine-harvester covered a distance of 100 m, a frame of 0.25 was placed across the width of the head in chess order in seven repetitions. Grain and corn ear parts with grains were collected from the areas defined by these frames and put into separate bags. In a laboratory, grains were weighted, and total grain loss in kg ha\(^{-1}\) was estimated.

Grain damage. During the research, different combine-harvester speeds and corn ear feedrates were applied as well as different cylinder peripheral velocity and concave clearances were used. During harvesting of corn ears, the forward speed of the combine-harvester, cylinder speed and fan speed as well as concave clearance and intervals between sieve scales shown in computer screen were registered in the cabin. As sample of 2 kg was taken from the grain flow coming from the grain auger to the tank. The sample was put into a bag attaching a label with a number and altered technological parameter. Then a second sample was taken, and only then technological parameter was altered. In a laboratory, six samples of 100 g were taken from each grain sample. In each sample, mechanically damaged grains were separated and weighted calculating average percentage of grain damage in each sample.

Combine-harvester efficiency. Forward speed, grain tank filling time, harvested area, and yield were registered during harvesting. After unloading the grain, they were weighted in the storehouse. Combine-harvester efficiency was calculated in ha h\(^{-1}\) and t h\(^{-1}\).

Fuel consumption. In a combine-harvester with axial threshing-separating rotor \(A\), there was a computer that showed hourly fuel consumption. When combine-harvester was harvesting corn ears in the marked section of 100 m long, the following computer readings were registered: forward speed, technological parameters of thresher and dynamics of engine hourly fuel consumption. Fuel consumption for producing one tonne of grains (1 t) was calculated as follows:

\[
B_{v} = \frac{10B_{g}}{L \cdot v \cdot A_{v}},
\]

where: \(B_{v}\) – hourly fuel consumption, l; \(L\) – corn head width, m; \(v\) – combine-harvester forward speed, km h\(^{-1}\); \(A_{v}\) – corn ear yield, t ha\(^{-1}\).

Statistical evaluation of research data. Experimental data has been processed in accordance with the statistical methods. The average value of the records and their confidence intervals \((P=0.05)\) are given. To establish the correlation of two factors, the curvilinear correlation coefficient \(R^{2}\) is calculated. Fisher’s criterion is used to find the curvilinear correlation of two factors. Regression equations are used to calculate the direction and size of the factor correlation.

Results and discussion

Meteorological conditions and corn biometrical indicators. In 2011, corns were harvested during the second decade of October, while in 2012 – in the third decade of October and second decade of November (Table 2). Meteorological conditions in October 2011 were favourable for ripening of corn since precipitation was 54.8 mm only, and the average temperature was 7.4 °C. From 13\(^{th}\) to 20\(^{th}\) October there were no precipitation; therefore harvesting conditions were very favourable. Average grain moisture level was 27.49 ± 0.48%.

<table>
<thead>
<tr>
<th>Indices</th>
<th>Measuring units</th>
<th>\textbf{Corn variety and harvesting time}</th>
<th>\textbf{Auxxel}</th>
<th>\textbf{Lapriora}</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>2011 10 18</td>
<td>2012 10 29</td>
<td>2012 11 13</td>
</tr>
<tr>
<td>Height of plants</td>
<td>m</td>
<td>2.51±0.029</td>
<td>2.24±0.054</td>
<td>2.04±0.035</td>
</tr>
<tr>
<td>Distance from soil to the first corn ear</td>
<td>m</td>
<td>0.96±0.037</td>
<td>0.98±0.040</td>
<td>1.09±0.047</td>
</tr>
<tr>
<td>Distance between adjacent plants in a row</td>
<td>m</td>
<td>0.176±0.014</td>
<td>0.163±0.012</td>
<td>0.171±0.014</td>
</tr>
<tr>
<td>Corn ear weight</td>
<td>g</td>
<td>221.56±22.74</td>
<td>242.46±24.83</td>
<td>236.86±18.69</td>
</tr>
<tr>
<td>Grain weight in an ear</td>
<td>g</td>
<td>181±17.27</td>
<td>177.76±21.74</td>
<td>186.51±6.77</td>
</tr>
<tr>
<td>Corn ear diameter</td>
<td>mm</td>
<td>44.62±2.04</td>
<td>44.50±1.90</td>
<td>45.0±1.85</td>
</tr>
<tr>
<td>Diameter of pith</td>
<td>mm</td>
<td>24.27±1.45</td>
<td>27.40±1.59</td>
<td>27.6±1.53</td>
</tr>
<tr>
<td>Weight of 1000 grain</td>
<td>g</td>
<td>399.56±6.33</td>
<td>396.30±5.95</td>
<td>356.60±4.80</td>
</tr>
<tr>
<td>Grain moisture content               %</td>
<td>28.51±0.59</td>
<td>32.66±0.26</td>
<td>36.71±0.21</td>
<td></td>
</tr>
<tr>
<td>Pith moisture content                %</td>
<td>49.79±1.18</td>
<td>64.77±1.82</td>
<td>53.46±9.36</td>
<td></td>
</tr>
<tr>
<td>Biological grain yield               t ha(^{-1})</td>
<td>11.1±0.25</td>
<td>9.97±0.31</td>
<td>9.26±0.83</td>
<td></td>
</tr>
</tbody>
</table>

In October 2012, precipitation was 75 mm; average air temperature was 7.4 °C. These conditions were unfavourable for corn ripening, therefore harvesting was postponed. Corn ears were harvested even in the beginning of November. During the first decade, precipitation was 35.6 mm; average air temperature was 5.9 °C. There was water
standing in the fields, and corn ears were already hanging down. The average moisture level of grain was 36.71 ± 0.21%, and even 53.46 ± 9.31% in piths.

Agrotechnics for corn growing, meteorological conditions and variety properties significantly affect biometrical indicators of corn ears. Technological parameters of combine threshing apparatus were defined after establishing average diameter of corn ears and piths. The clearance between the main tangential threshing cylinder rasp bars and the last crossbar of the concave must not exceed the average diameter of corn piths keeping the cylinder peripheral velocity as low as possible making sure there are no unthreshed grains.

**Total grain losses.** In 2011, Auxxel corn ears were harvested under favourable conditions using combine-harvester C. Grain moisture level was 28.51 ± 0.59%, and 49.79 ± 1.18% in piths. Different combine forward speeds and different corn feedrates were used (Figure 1). When the forward speed of the combine-harvester was 7.5 km h\(^{-1}\), and corn ears were fed applying rational federate of 16.7 kg s\(^{-1}\), total grain loss was 302.9 ± 20.6 kg ha\(^{-1}\), which amounted approximately 2.73% of total yield and did not exceed the allowable limit of 3%.

![Figure 1. Impact of Auxxel corn ear feedrate to the combine-harvester with tangential threshing apparatus C on total grain losses:](image)

- Cylinder peripheral velocity \(v = 12.2 \text{ m s}^{-1}\), concave clearance \(a = 27 \text{ mm}\), fan rotation speed \(n_1 = 1280 \text{ min}^{-1}\), distances between upper sieve scales \(b = 15 \text{ mm}\), distances between lower sieve scales \(b_2 = 20 \text{ mm}\), yield \(A_g = 11.1 \text{ t ha}^{-1}\), moisture content: grain \(U_1 = 28.51 \pm 0.59\)%, piths – \(U_2 = 49.79 \pm 1.18\)%, leaves – \(U_3 = 19.84\pm1.90\)%

In 2012, grain losses when harvesting high-moisture Lapriora crop using combine-harvester with axial threshing-separating device A, and combine-harvester with tangential threshing cylinder B were compared. Upon maximum allowable corn ear feedrate of 20 kg s\(^{-1}\), total grain losses using combine-harvester A were lower by 1.95 percentage units (Figure 2) compared to combine-harvester B. This difference of grain loss occurred due to the different construction of threshing-separating systems used in the combine-harvesters and specific operating conditions. Moisture level of corn grains harvested with the combine-harvester A was 32.66 ± 0.26%, and in case of the combine-harvester B, it was higher by 4.05 percentage units.

When increasing the feedrate to the combine-harvester A, grain loss was varying exponentially. Analogous grain loss variation pattern was found by Slovakian scientists (Poničan et al., 2009). When corn ears were fed to the axial threshing-separation rotor at the feedrate of 20 kg s\(^{-1}\), total grain loss was only 0.7%, since the grain moisture level was only 25%, concave clearance 32 mm, and rotor peripheral velocity 12.1 m s\(^{-1}\). They claimed that harvesting low-moisture corn ears, smaller amount of cobs and leaf debris gets into the cleaning shoe resulting in lower grain losses.

**Grain damage.** Grain damage mostly depends on corn feedrate, cylinder peripheral velocity, and concave clearance.

**Corn ear feedrate.** It has been determined that grain damage is minimal when corn ears are fed to the combine-harvesters at the rational feedrate of 20 kg s\(^{-1}\) (Figure 3). When feedrate was higher or lower, grain damage also increased. This depends on corn ear movement along the concave surface. In front part of the concave, corn ear movement speed is twice lower that when corn ears reach the end part of the concave (Jakushenkov, 1965). When feedrate is too small they move along the surface of the concave slower resulting in higher grain damage. When feedrate is excessive, concave becomes overloaded and reduce the movement speed resulting in higher grain damage.

Combine-harvester A has damaged more grain because high-moisture corn ears spent more time moving in the axial threshing apparatus compared to tangential apparatus. Corn ears were processed by rasp bars for a longer period of time. It has been established that when grain moisture level >30%, cracked grain amounted approximately 43% of all damaged grain resulting from the impacts of the rasp bars of threshing cylinder of the combine-harvester C. These data are similar to those published by other authors (Poničan et al., 2007).
Figure 2. Impact of Lapriola corn ear feedrate to the combine-harvester with axial apparatus A, and tangential apparatus B on total grain losses:

- combine-harvester A:
  \[ v = 16.0 \text{ m s}^{-1}, a = 25 \text{ mm}, n_i = 1150 \text{ min}^{-1}, b = 14 \text{ mm}, b_1 = 20 \text{ mm}, A_g = 9.97 \pm 0.31 \text{ t ha}^{-1}, U_1 = 32.66 \pm 0.26\%, U_2 = 64.77 \pm 0.82\%, U_3 = 38.85 \pm 1.74\% \]

- combine-harvester B:
  \[ v = 11.3 \text{ m s}^{-1}, a = 25 \text{ mm}, n_i = 1120 \text{ min}^{-1}, b = 18 \text{ mm}, b_1 = 20 \text{ mm}, A_g = 9.26 \pm 0.83 \text{ t ha}^{-1}, U_1 = 36.71 \pm 0.21\%, U_2 = 53.46 \pm 3.63\%, U_3 = 43.9 \pm 4.5\% \]

Cylinder peripheral velocity. When harvesting high-moisture corn ears, different cylinder speeds were applied. The first grains were separated from corn pith when rasp bars of the cylinder move at the speed of 7 m s\(^{-1}\), and all the grain are threshed when rasp bars move at the speed of 14 m s\(^{-1}\) (Vindizhev, 1996). The impact of peripheral velocity in tangential and axial threshing mechanisms was compared (Figure 4). It has been established that increasing rotor peripheral velocity in the threshing-separating unit of the combine A from 12 m s\(^{-1}\) to 18 m s\(^{-1}\), damage of high-moisture grain increased by 1.18 percentage units (Figure 4). Increase in the cylinder peripheral velocity in tangential threshing unit had more significant impact on grain damage: the difference was 5.81%. Results of the research are similar to those published in scientific articles (Wacker, 1990 and 2005; Poničan et al., 2009; Meši et al., 2012).
**Concave clearance.** Corn ears having different diameters are fed to the threshing. Their diameter depend on the variety, used agrotechnics, and meteorological conditions. To reduce grain loss and damage, it is necessary to adjust concave clearance during harvesting. When setting concave clearance, the variation range of corn ear and pith diameter must be taken into account. It has been established (Figure 5) that increasing the concave clearance from 25 mm to 40 mm, grain damage using combine-harvester with axial threshing-separating rotor was lower by 1.22 percentage units, and using combine-harvester with tangential threshing cylinder grain damage was lower by 0.99 percentage units.

![Figure 5](image-url)  
**Figure 5.** Impact of concave clearance on Lapriora corn grain damage (all parameters are given in Figure 3; \(m = 21.6 \text{ kg s}^{-1}\))

In the combine-harvester \(A\), grain damage was higher by 1.15 percentage units compared to the combine-harvester \(B\). Other authors (Poničan et al., 2009; Wacker, 1988) claim that axial threshing-separating unit cause less grain damage when mid-moisture corn ears are being threshed. P. Wacker has established that threshing corn ears where moisture level was 41%, 33% of grains were damaged because corn ears stayed longer in the axial threshing unit compared to tangential threshing unit.

**Combine-harvester efficiency.** The productivity depends on corn yield, corn head width, and combine-harvester forward speed. During the one technological hour, combine-harvester \(C\) with the attached 8-row corn head has threshed 48.42 ± 2.48 t of grains, and harvested 5.9 ± 0.3 ha of corn fields. Throughout the day, the average hourly productivity was 5.52 t lower because of the time periods spent waiting for the transport, troubleshooting, taking the longer tours around the field marking turning lines at headlands. Under unfavourable conditions, hourly productivity of the combine-harvester \(B\) with 12-row corn head was 51.98 ± 2.22 t threshed grain and 4.72 ± 0.64 ha of harvested corn fields. Average hourly productivity in separate corn fields was from 5.8% to 15.2% smaller. Under favourable conditions, combine-harvester \(A\) with axial threshing-separating unit and semi-tracked chassis has threshed 64.60 t of grains and harvested 5.87 ± 0.57 ha of corn fields within a technological hour. Under unfavourable conditions, the productivity reduced to 52 t h\(^{-1}\) of threshed grain.

**Fuel consumption.** Fuel consumption mostly depends on threshing unit and engine load. When field is even, and soil moisture level is consistent, the engine load mostly depends on combine-harvester forward speed and corn ears...
feedrate. It has been established by previous studies that when combine-harvester A drives over dry soil at the forward speed of 7 km h\(^{-1}\), hourly fuel consumption of the engine was 33.5 l (Špokas and Steponavičius, 2011). When the forward speed was increased from 2 km h\(^{-1}\) to 10 km h\(^{-1}\), fuel consumption increased by 7.8 l h\(^{-1}\). Total engine fuel consumption was established for harvesting Lapriora corn ears (Figure 6). Fuel consumption must be taken into account when calculating corn growing and harvesting costs, and also when planning fuel reserve for future harvest.

**Conclusion**

Corn feedrate variation for the combine with axial threshing-separating rotor A had less significant impact on total grain loss compared to the combine-harvester B with tangential threshing cylinder. When maximum allowable feedrate of 24.8 kg s\(^{-1}\) was applied in to combine-harvester B grain loss as compared with the combine-harvester A was 1.56 times higher.

The lowest rate of damaged grain was observed when applying rational feedrate of 20 kg s\(^{-1}\) of high-moisture corn ears. Grain damage rate in the case of combine-harvester A was lower compared to the combine-harvester B by 0.67 percentage units.

Cylinder peripheral velocity of the combine-harvester B may be adjusted from 12 m s\(^{-1}\) to 15 m s\(^{-1}\), while in the case of the combine-harvester A – up to 18 m s\(^{-1}\), because high-moisture grain damage does not exceed 5%. Grain losses during threshing must be reduced by altering concave clearance since the impact of the concave on grain damage is lower compared to the increase of cylinder peripheral velocity. In a tangential threshing unit, rational clearance between the rasp bars and the third crossbar of the main concave must be in the interval from 20 mm to 27 mm.

Rational operation of combine-harvester is achieved when fuel consumption for threshing one tone of grain is minimal, and grain loss does not exceed the permissible limit. It has been established that total grain loss and grain damage did not exceed the permissible limit when the feedrate of corn ears was 20 kg s\(^{-1}\) (Figure 2 and 3). Then the hourly engine fuel consumption was 90.5 l, and threshing of one tone of grain required 1.31 l of fuel.

**References**


**Figure 6. Impact of Lapriora corn ear feedrate on the combine-harvester A fuel consumption**

(all parameters are given in Figure 3)

Rational combine-harvester operation is observed when fuel consumption for threshing one tone of grains is minimal, and grain loss does not exceed the permissible limit. It has been established that total grain loss and grain damage did not exceed the permissible limit when the feedrate of corn ears was 20 kg s\(^{-1}\) (Figure 2 and 3). Then the hourly engine fuel consumption was 90.5 l, and threshing of one tone of grain required 1.31 l of fuel.
Epoxy Resin Filled with Glass Powder – Usage Possibilities in Agrocomplex

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Abstract

The article deals with adhesion and cohesion properties of filled epoxy resin with short curing time. The glass powder obtained from the recycling process of glass shards was used. The filling of reactoplastics leads to reduction costs with maintaining satisfactory mechanical properties. It is also a material recycling, which should be preferred. The adhesive bonding technology is in agrocomplex widespread way of joining materials. The companies developing adhesives in many cases cooperate with agricultural equipment manufacturers. As a example can be mentioned the cooperation between companies Henkel and New Holland. The experiment results quantify selected mechanical properties of filled epoxy resin and help expand the application area of filled reactoplastics.

Introduction

The polymeric materials are easily filled with various kinds of inorganic and organic fillers. These fillers optimize certain mechanical properties such as resistance to abrasive wear, tensile and flexural strength and also affect the price. The epoxy resins fall within the reactoplastics. These polymeric materials are cured by hardening agent. The curing creates a three-dimensional polymer net. Epoxies are used in a variety of industries including automotive and agriculture, primarily used for construction bonding. Filled epoxies can also use the properties of hard inorganic particles, which significantly increase resistance to abrasive wear (Byung Chul Kim et al. 2008). These materials can be used for the renovation of functional surfaces. Muller (2013) and Muller et al. (2013, 2011) mentioned in the field of agrocomplex application of filled epoxy resins on functional parts of combined harvesters and on the other agricultural equipments. Muller and Valasek (2012) described a significant increase of tribological properties of polymers using microparticles of aluminum oxide and silicon carbide. Inorganic microparticles based on waste - waste blasting material or ferrous metal chips can be used also (Valasek and Brozek 2013). Inclusion of these waste fillers into polymers creates material with specific properties, what is also way of material recycling.

The glass powder can be described as secondary material, which is a product of the glass shard recycling, mostly packaging glass. This material has suitable properties used for manufacture of roofing, foam glass and it is used for filling polymeric materials also. Ku and Wong (2012) optimize by glass powder tensile and flexural properties of the epoxy and phenolic resins. The glass powder with dimensions of 2–32 μm was used. Inclusion of glass powder led to decrease of tensile strength from values 15.0 MPa to 10.14 MPa (5 wt%) and subsequent to increase up to value 12.6 MPa (12.5 wt%) (Ku et al. 2010).

The aim of the experiments was to quantify the impact of glass powder inclusion on cohesion and adhesion characteristics for fast cure epoxy resins. The experiment is based on hypothesis arising from the literature review that the glass powder can optimize the strength characteristics of reactoplastics. The description of influence of glass powder on properties of epoxies with short curing time allows consider filling the polymeric materials used in agrocomplex. This kind of filling materials can lead to optimization costs and mechanical properties together with secondary materials using. Due to environmental the material recycling of waste should be preferred.

Material and Methods

Two component Epoxy resin (EP) Gluepox Rapid was filled. This resin is characterized by high fluidity and short curing time. It is suitable for bonding metals, glass, wood and ceramics. Resin density is 1.14 g·cm$^{-3}$. Short curing time eliminates sedimentation, which is undesirable in case of filling reactoplastic by particle (Valasek et al. 2012).

The glass powder (GP) Refaglass of particles sizes smaller than 90 μm was used in the described experiment – given by producer Recifa s.c., CZ, the organic dirt do not exceed 1% according to the producer. Glass powder density is 2.5 g·cm$^{-3}$.

The mixture of filler and epoxy resin was prepared by mechanical mixing. Test specimens were cast into forms made of the silicone rubber and specimens were cured according to the technological requirements of the resin manufacturer at room temperature of 23 °C. The bonded joint was made with same mixture as casted specimens. The mixture was prepared with varying amounts of filler in the matrix, 5 to 30 volume percent.

As a quality indicator of filled polymers can be considered porosity ($P$), which was calculated based on the difference between theoretical and real density according to the equation (1):

$$P = \frac{\rho_{\text{Teo}} - \rho_{\text{Rea}}}{\rho_{\text{Teo}}} \cdot 100 \%,$$

where: $P$ – porosity (%),
\(\rho_{\text{Teo}}\) – theoretical composite density (g·cm$^{-3}$),
\(\rho_{\text{Rea}}\) – real composite density (g·cm$^{-3}$) (Berthelot 1998).

The hardness measurements were performed using Shore D (CSN EN ISO 868). Adhesive and cohesive characteristics of the system are described by tensile test of universal specimens made from a casted EP/GP mixture and through the shear strength of rigid adherend where the joint (gap) was made of EP/GP mixture.
For the lap-shear strength description in the boundary adherend – composite system the lap assemblies were made. The surface of 1.5 mm thick steel sheets, onto which the composite system was applied, was at first blasted using the synthetic corundum fraction F80 under the angle of 90°. In this way the average surface roughness of Ra = 1.58 ± 0.28 µm was reached. Then the surface was cleaned and degreased using perchlorethylene and prepared to the composite mixture application. The test specimens determined for the specification of the cohesive strength by means of the tensile strength were prepared according to the requirements of the standard CSN EN ISO 3167. The setting of the tensile characteristics was carried out in accordance with the standard CSN EN ISO 527. The representation of fracture surface and adhesive layers were carried out using a stereoscopic microscope.

A statistical evaluation of results was carried out by means of a program Statistica – one factor ANOVA, reliability level α = 0.05. For statistical comparison of conformity was T-test used when the null hypothesis H₀ (p > 0.05) corresponding to the average of data sets without any significant statistical difference.

Results

The porosity and theoretical density of the filled systems is shown in Fig. 1. Porosity is caused by bubbles, which affect the mechanical properties. The presence of air bubbles is due to the preparation procedure, which was chosen with regard to the application area of agrocomplex, where is not vacuum or mixing equipment supposed. The hardness Shore D is shown in Fig 1. according to a variable concentration GP in epoxy. Epoxy hardness 89.57 ± 0.83.

<table>
<thead>
<tr>
<th>Filler (%)</th>
<th>ρ_{teo} (g·cm⁻³)</th>
<th>P (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>1.21</td>
<td>1.03</td>
</tr>
<tr>
<td>10</td>
<td>1.28</td>
<td>3.36</td>
</tr>
<tr>
<td>15</td>
<td>1.34</td>
<td>1.65</td>
</tr>
<tr>
<td>20</td>
<td>1.41</td>
<td>2.13</td>
</tr>
<tr>
<td>25</td>
<td>1.40</td>
<td>1.63</td>
</tr>
<tr>
<td>30</td>
<td>1.55</td>
<td>3.87</td>
</tr>
</tbody>
</table>

Figure 1. Density, porosity of composite systems (left), hardness of composite systems (right)

The Fig. 1 shows a slight increase of hardness with increasing concentration of filler in the matrix. When using a T-test to compare middle values it can be stated that in the interval from 5%GP to 25%GP data sets are statistically identical. When comparison 5%GP with 30%GP this hypothesis is not valid, p = 0.02.

The graphical representation of tensile strength of universal test specimens and elongation is shown in Fig 2. With increasing share of GP in epoxy there was a decrease in tensile strength (from middle values of 40.82 ± 3.44 MPa to 27.48 ± 2.39 MPa). Variation coefficient of measurements did not exceed 9%. Elongation values decreased from 2.60% to 0.99% (variation coefficient does not exceed 17%). Tensile strength of unfilled resin corresponds to 51.42 ± 3.20 MPa (6.18% elongation). When using T-test, values of tensile strength in the interval 10–25%GP are the same p > 0.10.

Figure 2. Impact strength and Elongation of composite systems
Typical appearance of the fracture surface is shown in Fig. 3. The occurrence of air bubbles can lead to the initiation of cracks.

Figure 3. Fracture surface (25%GP)

The shear strength of solid steel lap adherend is shown in Fig 4. Shear strength of joints composed of unfilled epoxy corresponded to 11.40 ± 0.87 MPa (gap width 0.1 mm). The highest shear strength was observed in system of 25%GP – 12.89 ± 2.39 MPa. The system of 30%GP there was 6% decrease in tensile strength compared to that value. In the interval of 20%GP to 30%GP T-test was used with p > 0.13. These results demonstrate that the mixtures with a higher concentration of GP have higher shear strength of lap joint. The gap width was defined only for filled epoxy. The gap width increased with increasing share of GP: 0.15 mm (5%GP) to 0.23 mm (30%GP).

Figure 4. Lap-shear tensile strength

Type of the bond destruction was evaluated on the stereoscopic microscope. In all cases of filled epoxy resins (unfilled epoxy also) adhesive type of failure (AF) has occurred. The concentration of 25%GP and 30%GP in some cases showed a special type of the cohesive failure (SCF), see Fig 5.

Figure 5. Characteristic types of failure – left SCF 25%GP, right AF 5%GP
Conclusion

The experiment showed that the inclusion of GP in epoxies can optimize lap shear strength of rigid adherend. In this case, there was 13% increase in shear strength compared to unfilled resin (system of 25%GP). However, it is important to realize that this paper does not address the optimal join thickness (gap width) that affects the maximum strength of adhesive.

The shear strength significantly deteriorated with the addition of GP, which contradicts with results of Ku and Wong (2012). The decline stabilization of strength occurred between 5%GP to 25%GP, when higher concentrations of filler (30%GP) led to a further decrease in strength. From this point of view is the optimal concentration for application in agrocomplex for this epoxy (Gluepox Rapid) concentration of 25%GP in the matrix. Higher concentrations reduce the price of epoxy, optimize shear strength (which is limited by adhesion destruction) but decrease the tensile strength (cohesion strength). Finally, the presence of GP resulted in a slight increase of epoxy hardness. Limiting factor of described system is the presence of air bubbles. The porosity would to go reduce by a preparation process of the mixture (test specimens).

The carried out experiment showed following:

- Inclusion of glass powder and reactoplastics is possible and leads to material usage of waste.
- Mechanical properties of filled reactoplastics are proportional to the varying concentration of glass powder.
- In the agrocomplex these materials can assert at cementing and bonding scuttle, cracks in machine boxes, it can serve for planishing welding seams, for reparation of small cracks, for caulking cracks in tank and not last for bonding materials.

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References


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CFD Analysis of Broiler House Ventilation Patterns with Respect to the Poultry Welfare

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Abstract
This paper is focused to the broiler house ventilation in summer and winter periods with respect to main welfare needs of poultry during the fattening period. Limits of ventilation configurations are given with the minimum air exchange during the beginning of fattening in winter on the one side and the maximum air exchange during the end of fattening in summer on the other side. Basic parameters of analyzed cases are set up with respect to the technical standards. Several 2D CFD (computer fluid dynamics) models for every configuration are solved using the Ansys Fluent software and discussed from different points of view with focus to the welfare of animals. The main part of work is focused onto finding the most usable configuration of inlets and outlets. Appropriate effects of longitudinal and transversal ventilation are used in different flow regimes. It is also mentioned, that mainly during the winter period, when the flow rate of the air through the interior is reduced to minimum, the concentration of pollutants and also the humidity becomes the main criterion for the ventilation system control.

Introduction
There is a great number of factors, which have an influence onto the forming an internal conditions inside a broiler houses. The need of an exact control of internal conditions inside the broiler house is forced by two main factors. It is the cost of sources and energy which are needed to satisfy welfare of animals (Weeks and Butterworth, 2004) and on the other side, there is a need of production process intensification. There is an interesting comparison of broilers growth characteristics in history (Lesson and Summers, 2000), Table 1 illustrates such this principle for the US farms.

Table 1. Growth characteristics of mixed-sex broilers grown to typical “market weights”

<table>
<thead>
<tr>
<th>Time period</th>
<th>Age [days]</th>
<th>Live weight [kg]</th>
<th>Live weight gain [g.day⁻¹]</th>
<th>Feed gain [-]</th>
<th>Mortality [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1920’s</td>
<td>120</td>
<td>1.0</td>
<td>8</td>
<td>5.0</td>
<td>20</td>
</tr>
<tr>
<td>2000’s</td>
<td>50</td>
<td>2.7</td>
<td>54</td>
<td>1.9</td>
<td>4</td>
</tr>
</tbody>
</table>

It is clear, that the fulfillment of welfare conditions and their combination with effective energy and space management should leads to an optimum production quality with long term efficiency. Intensification of fattening process brings the higher demands for the ventilation and heating systems of facilities and precision of their adjustment. The aim of this paper is to use computer fluid dynamics system (CFD) to compare a set of ventilation variants with respect to summer and winter conditions in a very simple shaped broiler house as a part of the welfare making where its needs and energetically demands are in a strict opposition.
The main motivation for this work was the result of earlier research (Zajicek and Kic, 2012). Fig.1 shows the comparison between the numerical simulation and existing broiler house as an example result which were used for the tuning the CFD model.

**Materials and methods**

The Ansys Fluent – computer fluid dynamics (CFD) software - is used to solve variants of broiler house ventilation. The transversal cross section of a typical broiler house used for this simulation is sketched at Fig 2.

![Crosssection of broiler house](image)

**Figure 2.** The crossection of broiler house with basic dimensions and computational grid for CFD calculation at variant A (see Fig. 3)

It is 15 meters wide and 3 meters height rectangle with inlets and outlets on sides. For two solved cases, there is also the top positioned inlet/outlet used. The configuration of inlets and outlets used for analysis is shown at Fig. 3. All variants are marked with letters from A to H. Solution of CFD model was made for summer and for winter conditions for every of them and the comparison is made.

![Configuration of inlets and outlets used for CFD simulation](image)

**Figure 3.** Configuration of inlets and outlets used for CFD simulation

All analysis shown here includes the flow analysis including the natural convection where the air is considered as ideal gas, thermal analysis including the heat generation of the poultry and also the heating system used during the winter period. The heat transfer through the walls and floor is also included into the calculation.

Boundary conditions were obtained according the Czech technical standards (anon, 1998) and the same conditions are adjusted in all variants of every season. The EES (Engineering equation solver) software (Yunus, 2002) was used as a tool for this preparing phase calculation. After this the simple geometrical and numerical model of 2 dimensions was prepared using the Gambit preprocessor. The each variant was then solved using the Fluent solver and after convergence of each 16 variants the results was compared for summer and winter conditions.

CFD computed values were exported as a profile file, which were parsed by specially written code, which extracted data for comparison of all cases. The evaluation of these results (mainly graphs) was done with the R software (Henry and Stevens, 2009) and Adobe Indesign (Williams, 2011) software was used for comparison of graphical outputs.

**Results and discussion**

Results presented here are only a small fragment of total amount of data obtainable through the CFD simulation. It has to be mentioned, that all results are evaluated for the same values of total flow rate in every case of each season and the parameters of turbulence models (RNG-kε) are also the same. All cases were converged with residuals lower then $10^{-3}$. 
Results for summer variants: Fig. 4 and Fig. 5 show the Temperature and velocity profiles as a graphs representing values of quantities on transversal line at the height of 0.3 m above floor. This position was used because this is responds to the height of broilers and also because this is a good position for making a measurements in a real broiler houses. Fig. 6 shows contours of temperature and velocity magnitude.

It can be seen, that for summer conditions the variants B, C and D can be marked as useful cases, as for the relatively small velocities in the zone of animals as for relatively low temperatures in this place. Cases A and E has a characteristically shaped flow field, which leads to bad ventilation inside the central part of the space and high temperatures in this area, therefore that can be marked as a worst variants for summer.

Results for winter variants: Fig. 7 and Fig. 8 show the Temperature and velocity profiles as a graphs representing values of quantities on transversal line at the height of 0.3 m above floor. Fig. 9 shows contours of temperature and velocity magnitude. The overall temperature level is given by volumetric heat source which represents the heating system. The variant E is the favorite of the comparison, because of relatively higher temperature level in the zone of animals according to other cases, but the great care has to be taken onto the ventilation effect, which is relatively small in central part of the building. This ventilation effect corresponds with comparison of CO$_2$ concentration profile, which is also shown for winter - Fig. 10, because in this period it is the main factor which is used to determining the amount of fresh air which has to income into the ventilated area. The shape of NH$_3$ mass fraction profiles obtained from this simple model is the same one, only the values on y axe are in the range from 0 to 2.3.10^{-6} [kg.kg$^{-1}$], because of using the mixture template model with generation of species inside the same fluid zone only with different intensity of production. It has to be mentioned, that the convergence of the solution for winter conditions is very slow and it is not easy to obtain good solution, mainly because of low velocities in a great areas of the space and greater influence of natural convection (in winter there are greater temperature gradients between the incoming cold fresh air and heated air inside the building), which leads to fragile stability of solution.

The variant H also can be important for winter conditions. Its benefit is mainly the highest and most homogeneous temperature value inside the animals zone, which is paid by greater concentration of pollutants, but, if the ventilation for this configuration will be intensive enough, the well-being of animals can be seen as the best.

Variants F and G aren’t useful for this shape of broiler house cross-section. It is mainly because of great velocities, which can be observed nearby the floor, where such intensive air stream can leads to welfare problems of animals and can leads to their thermal discomfort.

It is interesting to mention also the problems which arise in case of comparison of the relatively large amount of solved problems where the most important fact is to compare the comparable. The comparable results presented needs to use exactly the identical geometrical models (no grid adaptation and shape manipulation). The variants are distinguished only by different types and values of the boundary conditions and, as already mentioned, all results presented here correspond to the same total air flow. The equivalent file and directory structure of results was produced for each solved case, and therefore the extracting of needed profiles and graphical representations of flow field can be done automatically by the own written program which produced the same color scales for all tasks and extracting the data profiles used for x-y plots of values.

It is also relatively hard to make graphical output from Fluent with exactly the same positioning and size. This problem was solved by creating the journal file originated from the usage of graphic driven menu. This journal is rather complicated and was rewritten for a universal usage on each solved case. This programming work was a little bit time consuming, but after finishing it is possible to make exactly the same set of contours (velocities, temperatures …) with the same color scheme (Color, BW, with black or white background) and exactly the same size and resolution. Such graphical outputs can be processed using the graphical batch conversion tools. After cropping, rotating and sorting it is possible to make the comparison figures as they are presented in this paper.

The R (http://www.r-project.org/) software, which is an integrated suite of software facilities for data manipulation, calculation and graphical display, was used very effectively as a tool for making required graphs and authors are very satisfied with its possibilities. For example it is practically impossible to create graph at Fig. 1 using MS-Excel, because of combining the large number of computed values with only a few experimentally obtained values. With R it is possible very easily.
Figure 4. Temperature profiles at the level of measurement for summer conditions

Figure 5. Velocity profiles at the level of measurement for summer conditions

Figure 6. Contours of temperature and velocity magnitude for summer conditions
Figure 7. Temperature profiles at the level of measurement for winter conditions

Figure 8. Velocity profiles at the level of measurement for winter conditions

Figure 9. Contours of temperature and velocity magnitude for winter conditions
Figure 10. The CO$_2$ mass fraction at the level of measurement for winter conditions

Conclusions

Thanks to the CFD simulation is possible to obtain the great amount of results and as it is shown, it is rather difficult to compare them. Before making the CFD model of such and similar problem, it is very important to make it as easy as it is possible, but on the other side, it has to cover all important physical aspects of explored problem. The reduction of changeable parameters for model is also very important. In presented comparison the only parameter for each season was only opening or closing inlets and outlets. Next step can be taking of only one variant and start to observe the influence of another parameter, such as input stream direction, geometry changes, more detailed simulation of heat and pollutant sources and others, but what is important is the comparing of comparable. It is also very important to find the way, how to organize results and effectively combine data from variants, taking care about same limits for graphs, same scales for contours and others similar details. It isn’t possible to find the best case, which can be the absolute winner from all points of view, but the characteristics obtained by simple 2D simulations can help to choose good and usable variants (B, C, D for summer and E, H for winter) and eliminate the bed ones, where observed values, or their gradients are unacceptable. The final decision about the technical solution of ventilation system cannot be done at the basis of presented analysis, but it is possible to reduce the amount of configuration variants which has to be solved more precisely with sharply defined boundary conditions specific for individual engineering project.

Acknowledgements. The access to computing and storage facilities owned by parties and projects contributing to the National Grid Infrastructure MetaCentrum, provided under the programme "Projects of Large Infrastructure for Research, Development, and Innovations" (LM2010005) is highly appreciated/acknowledged.

References

Investigation of Technological Processes of Wheat Straw Preparation for the Synthetic Diesel Fuel Production

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Abstract

The straw of cereals could be utilized for synthetic diesel fuel production. The research of raw materials preparation technological processes to produce synthetic diesel fuel is relevant, because this scientific area is little investigated. The physical-mechanical properties of these raw materials are important for handling and transportation processes. From these properties depends harvesting of raw materials, storage, transportation logistics, conversion technology and selection of equipment and operation. The work carried out on winter wheat straw preparation of synthetic diesel fuel production processes and raw materials physical-mechanical properties. There were established the chopped and milled wheat straw physical-mechanical properties (chaff moisture content, bulk density, fineness, natural slope and fall angles and a coefficient of dynamic friction), and required energy consumption for straw milling. It was found that flow angles at various processing stages of synthetic diesel differed slightly, and milled wheat straw bulk density was more than two times higher than chopped. Wheat straw chaff fraction was significantly coarser than mill: more than 2 mm particles of chopped wheat straw were 69.30±2.63%, and wheat straw mill was only 7.36±1.85%. Dust of investigated variants amounted to 4.02±1.17 and 7.83±1.52% respectively. It was determined that after three-times increase in the supply of wheat straw chaff mass to the mill, the power consumption of the milling increased by approximately three times (273%), and mill productivity increased only about two times (204%). While increasing of wheat straw chaff load and movement velocity, the dynamic friction coefficient and, respectively, the optimal inclination angles of raw material storage and transportation implements walls decreases.

Key words: wheat straw, physical-mechanical properties, chopping, milling, flow angles, energy consumption, a dynamic coefficient of friction.

Introduction

Even if urging to improve first-generation biofuel production technologies in order to increase their competitiveness in the market, the European Commission, however, pays the greatest importance to the second generation of biofuel research and its deployment in the nearest future. It is related to a high potential of cellulose containing raw materials, including waste, and beneficial properties of second-generation biofuel (Forans, 2009; Krzesinski, 2006; Odenwald, 2011).

While meeting the foreseen challenges, the European Commission included the second generation (synthetic) fuels scientific research in the basic research programs (FP7, Energy, “Intelligent Energy”, etc.). Presently, some research regarding the use of second-generation biomass fuel production has been started, and the created technologies are tested to get installed in the industry (Forans, 2009; Heil and Wirtgen, 2004).

In Lithuania, the initial second-generation biofuels production studies were carried out in the implementation of the Industrial Biotechnology Development in Lithuania for 2007-2010 Program, but their results are not sufficient for implementation of experimental technologies in our country sites (Grazuleviciene et al, 2011; Janulis, 2004; Lebedevas et al, 2010; Lebedevas et al, 2006; Sendzikiene, 2005).

During catalytic synthesis of diesel, unlike the well-known biomass decomposition processes, organic matters are converted not to methane molecules and carbon, but to CH\textsubscript{2} radicals with the ability to adjust the length of the hydrocarbon chain. This process lets us to avoid harmful and polluting substances that in high temperatures can form dioxins and furans (Raiia and Navickas, 2008).

Biomass resources can be divided into two groups:
1) relatively dry biomass (moisture content 15–20\%):
   • fuel wood and wood waste;
   • fast-growing woody plants;
   • straw;
   • turf.
2) relatively wet biomass (moisture content 70–95\%):
   • grass;
   • fast-growing herbaceous plants (Jerusalem potato, Chinese reed, \textit{Pennisetum purpureum}, etc.)
   • sewage sludge;
   • manure, animal (animal carcasses) waste;
   • production of ethanol-alcohol soluble.

Straw can become one of the most important raw materials for synthetic diesel fuel production because of the increasing crop areas. Barley and wheat straw is rich in cellulose, hemicelluloses and lignin (Wisniewska et al, 2003).

Canadian researchers studied physical properties, chemical composition and calorific value of the various types of biomass (wheat and barley straw, flax straw, grass, pine wood) (Naik et al, 2010). It was found that calorific value of wheat straw and pine wood was higher than that of barley straw and grass. While burning barley straw, the highest amount of ash (9.8±0.1\%) formed. Wheat straw ash was 1.3±0.1\%, flax stalks – 3.0±0.2\%, timothy – 1.1±0.1\%, and pine wood – 1.5±0.2\%. The minimum amount of alcohol (2.1 g) was found in wheat straw and the highest (8.0 g) – in flax stalks. It was found that the highest amount of cellulose and hemicelluloses is present in pine wood, whereas the highest amount of lignin was found in timothy (24.0 g).
Physical-mechanical properties of straw used for production of synthetic diesel and its technological processes are started to get explored in Lithuania. It is vital to continue researches in this direction.

The purpose of the research – to determine physical-mechanical properties (chaff moisture content, bulk density, fineness, flowing angles, a dynamic coefficient of friction) of wheat straw prepared for production of synthetic diesel fuel, as well as energy needs for its crushing.

Object and research methods

The object of the research – winter wheat Zenta straw grown in Radviliškis area, and technological processes during its preparation for production of synthetic diesel. The straw was chopped by drum chopper Maral-125 (Option 1), and then it was milled by grind mill Retsch SM 200 (Option 2).

The drying-weighing method was employed to measure chaff moisture (Naik et al, 2010). Samples were weighed by electronic laboratory scales SCALTEC, the measurement range of which is 310 g, and the measurement error is 0.01 g. To set constant weight, samples were dried in the oven BINDER at the temperature 105ºC.

While determining the bulk density of winter wheat straw chaff, the chopped plant material was freely (without pressure) poured to 500 ml cylindrical vessel till the upper edge. The vessel with the chaff was weighed, and, knowing an empty and full vessel volume and mass, mass of wet bulk density of the material and dry material (humidity setting weight) was calculated (Jasinskas et al, 2010).

Quality of chaff fineness was determined by using the sieves. Chaff was weighted on sieves with different diameter holes remaining fraction (Urbonas and Zinkevicius, 2012). 60 g of crushed and milled wheat straw samples were weighted by electronic laboratory scales SCALTEC. Each wheat straw chaff and flour sample was shaken and sieved on a sieve with 2 mm, 1.25 mm, 1 mm, 0.5 mm and 0.315 mm diameter round holes. The remaining on the sieves wheat straw chaff was weighed and the percentage of each fraction was calculated.

A simple stand was used to determine natural slope and fall of angles of wheat straw chaff (Fig. 1) (Urbonas and Zinkevicius, 2012). 2 kilos of chaff were poured into a rectangular container. Having opened the valve 1, a certain percentage of wheat straw chaff spilled out on the horizontal surface 2 on the floor. Chaff fall angle \( \alpha_{gr} \) was measured by the protractor ruler in the container with the rest of the chaff; and on the floor, the natural slope angle \( \alpha_n \) was measured in the spilled over chaff. Each test was repeated 5 times.

Slope angle of dispenser, storage bunker walls, and transfer duct were chosen according to the physical-mechanical properties of friable materials. K. V. Alferov studies have shown that the optimal angle \( \alpha_i \) depends only on the friable material coefficient of friction with hopper walls \( f_i \) (Jasinskas et al, 2010):

\[
\cos \alpha_i = \sqrt{\frac{4}{f_i^4 + 1} - 2f_i^2}.
\]

The friction coefficient is calculated by the following formula:

\[
f_i = \frac{F_f}{F_0},
\]

where: \( F_f \) – the friction force, N;

\( F_0 \) – the normal pressure force, N.
A special stand was used to identify the coefficient of dynamic friction (Fig. 2). 100 g of wheat straw chaff was poured into the cylindrical vessel with a bottom area of 16.5 cm². 1 mm gap was left between the vessel wall and the tested surface. The friction force was set by strain-gauge steel ring. Surface to be tested was pulled by the pulling mechanism, and the self-recording device wrote down the data. Wheat straw chaff load was modified by 1 kg weights, and the moving speed of the tested surface was measured by the cylinder pulling mechanism.

The coefficient of dynamic friction was determined by sliding metal (roughness 0.51 ± 0.01 μm), wooden (roughness 8.47 ± 2.13 μm) and plastic (roughness 0.25 ± 0.01 μm) surfaces. Tests were repeated 5 times.

Chopped by a drum chopper samples of wheat straw of 25 g, 50 g and 75 g were supplied to the mill Retsch SM 200 (Jasinskas et al., 2013). Productivity of the mill was set by the timer while measuring the duration of milling and then converting into tons per hour.

Energy consumption needed for milling wheat straw was determined by measuring the loaded and non-loaded mill electric motor energy consumption (kW·h). The three-phase portable power network analysis device Metrel Q Plus was used to measure mill electric motor energy consumption (kW·h). Tests were repeated 5 times.

While determination of main physical-mechanical properties of winter wheat straw used in preparation of synthetic diesel fuel production, it were fixed only some optimal parameters, because there are no special requirements for determination of these properties.

Results of research

Moisture content of wheat straw chopped by the drum chopper reached 12.19 ± 2.05%, and bulk density of the chaff was only 0.062 ± 0.003 g/cm³, and the dry material density was 0.054 ± 0.003 g/cm³ (Table 1). Meanwhile, density of the mill ground wheat straw was 0.1300 ± 0.013 g/cm³, and the density of the dry material was more than 2 times higher – 0.1140 ± 0.013 g/cm³.

Table 1. Physical-mechanical properties of wheat straw used in production of synthetic diesel fuel production

<table>
<thead>
<tr>
<th>Indexes</th>
<th>Wheat straw chopped by the drum-type forage harvester &quot;Maral-125&quot; (Option 1)</th>
<th>Wheat straw chopped by the drum-type harvester and mill &quot;Retsch SM 200&quot; (Option 2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chaff weight (g) in 500 ml vessel</td>
<td>32.08±1.91</td>
<td>65.0±7.38</td>
</tr>
<tr>
<td>Chaff dry mass weight (g) in 500 ml vessel</td>
<td>27.3±1.91</td>
<td>57.1±7.38</td>
</tr>
<tr>
<td>Chaff bulk density (g/cm³)</td>
<td>0.062±0.003</td>
<td>0.130±0.013</td>
</tr>
<tr>
<td>Chaff dry mass bulk density (g/cm³)</td>
<td>0.054±0.03</td>
<td>0.114±0.013</td>
</tr>
<tr>
<td>Natural slope angle α, deg.</td>
<td>33±11</td>
<td>31±13</td>
</tr>
<tr>
<td>Fall angle α, deg.</td>
<td>62±11</td>
<td>73±12</td>
</tr>
</tbody>
</table>

Flow angles of the analyzed raw materials used for production of synthetic diesel slightly differed (Table 1). Natural slope angle of the wheat straw chopped in a drum chopper Maral-125 was 33 ± 11 deg., and that of the wheat straw chopped in the mill Retsch SM 200 was 31 ± 13 deg. Fall angle was 82 ± 11 deg. and 73 ± 12 deg. respectively.

During separate stages of wheat straw preparation for synthetic diesel fuel production, their fineness (fractional composition) differs significantly (Table 2). Mostly, there were larger than 2 mm particles 69.3 ± 2.63% chopped by a drum chopper Maral-125. Meanwhile, the number of larger than 2 mm particles of wheat straw milled in the mill Retsch SM 200 was only 7.36 ± 1.85%. For comparison, similar studies were carried out with elephant grass (Miscanthus sinensis) growing in Germany used for production of synthetic diesel, the number of larger than 2 mm particles was 2.69 ± 0.91% (Urbonas and Zinkevicius, 2012).

Table 2. Fineness of wheat straw in preparation for synthetic diesel fuel production (fractional composition)

<table>
<thead>
<tr>
<th>Indexes</th>
<th>Diameter of sieve holes, mm</th>
<th>Wheat straw chopped by the drum-type forage harvester &quot;Maral-125&quot; (Option 1)</th>
<th>Wheat straw chopped by the drum-type harvester and mill &quot;Retsch SM 200&quot; (Option 2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>On the sieve remaining fractional part, g and %</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ø 2 mm</td>
<td>41.6±1.52 g</td>
<td>69.3±2.63 %</td>
<td>4.41±1.71 g</td>
</tr>
<tr>
<td>ø 1.25 mm</td>
<td>1.980±0.25 g</td>
<td>3.31±0.42 %</td>
<td>3.55±0.60 g</td>
</tr>
<tr>
<td>ø 1 mm</td>
<td>4.08±0.93 g</td>
<td>6.80±1.56 %</td>
<td>13.48±3.11 g</td>
</tr>
<tr>
<td>ø 0.5 mm</td>
<td>7.05±1.1 g</td>
<td>11.75±1.82 %</td>
<td>26.5±2.64 g</td>
</tr>
<tr>
<td>ø 0.3 mm</td>
<td>2.88±0.46 g</td>
<td>4.80±0.77 %</td>
<td>7.36±1.02 g</td>
</tr>
<tr>
<td>ø 0 mm (dust)</td>
<td>2.41±0.3 g</td>
<td>4.02±1.17 %</td>
<td>4.70±0.91 g</td>
</tr>
</tbody>
</table>

A lot of dust was found in the wheat straw milled in the mill – 7.83 ± 1.52%. Almost twice less dust was found in wheat straw chopped in a drum chopper – 4.02 ± 1.17%. Thus, larger than 2 mm particles of wheat straw were gotten from a drum chopper Maral-125; whereas particles of wheat straw milled in the mill Retsch SM 200 were of the size 0.5–1.0 mm.

Having performed dynamic friction tests of wheat straw chopped in a drum chopper and the mill Retsch SM 200, it was found that, while sliding on a metal surface, the coefficient of dynamic friction decreases with the increase of
velocity (Fig. 3). For example, the coefficient of dynamic friction $f$, where $N_0 = 1$ N with the increase of speed from 0.022 to 0.081 m/s, decreased from 0.470 to 0.362 (about 23%), and at normal pressure force $N_0 = 31$ N, only from 0.263 to 0.237 (only about 9.9%).

Figure 3. Coefficient of dynamic friction of milled wheat straw sliding on metal surface:
load 1 N – $f = -1.842v + 0.511$, $R^2=0.828$; load 11 N – $f = -0.620v + 0.329$, $R^2=0.934$; load 21 N – $f = -0.817v + 0.312$, $R^2=0.994$; load 31 N – $f = -0.447v + 0.273$, $R^2=0.911$

Similar results were obtained for the milled wheat straw sliding on wooden and plastic surfaces (Table 3). Coefficient of dynamic friction of wheat straw flour sliding on a wooden surface was the highest. The highest dynamic friction coefficient (0.972) was obtained with 1 N wheat straw chop load and velocity of 0.022 m/s. Wheat straw chaff sliding on metal surface at the speed 0.022 m/s and with 1 N load, dynamic friction coefficient was 0.470; and while sliding on plastic surface, the coefficient was 0.656. Accordingly, with 31 N load and 0.022 m/s speed, dynamic friction coefficients were as follows: wood – 0.402, metal – 0.263, and plastic – 0.3.

Table 3. Research results of chopped and milled wheat straw (Option 2) dynamic friction

<table>
<thead>
<tr>
<th>Sliding surface</th>
<th>Mass movement speed $v$, m/s</th>
<th>Dynamic coefficient of friction $f$ while acting of normal pressure force</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 N</td>
<td>11 N</td>
</tr>
<tr>
<td>Wood</td>
<td>$f = -5.79v + 1.099$, $R^2=0.992$</td>
<td>$f = -1.287v + 0.605$, $R^2=0.786$</td>
</tr>
<tr>
<td>0.022</td>
<td>0.972</td>
<td>0.577</td>
</tr>
<tr>
<td>0.038</td>
<td>0.879</td>
<td>0.556</td>
</tr>
<tr>
<td>0.054</td>
<td>0.786</td>
<td>0.536</td>
</tr>
<tr>
<td>0.068</td>
<td>0.705</td>
<td>0.517</td>
</tr>
<tr>
<td>0.081</td>
<td>0.630</td>
<td>0.501</td>
</tr>
<tr>
<td>Plastic</td>
<td>$f = -3.42v + 0.731$, $R^2=0.951$</td>
<td>$f = -0.456v + 0.424$, $R^2=0.964$</td>
</tr>
<tr>
<td>0.022</td>
<td>0.656</td>
<td>0.414</td>
</tr>
<tr>
<td>0.038</td>
<td>0.601</td>
<td>0.407</td>
</tr>
<tr>
<td>0.054</td>
<td>0.546</td>
<td>0.399</td>
</tr>
<tr>
<td>0.068</td>
<td>0.498</td>
<td>0.393</td>
</tr>
<tr>
<td>0.081</td>
<td>0.454</td>
<td>0.387</td>
</tr>
</tbody>
</table>

Optimal inclination angles of storage and transportation facilities walls of wheat straw chopped in a drum chopper and milled in a mill Retsh SM 200, with the chaff lowest speed (0.022 m/s), and the load variety from 1 to 31 N are as follows (Table 4): when the wall is made of metal – 21–38 deg., plastic – 24–48 deg., and wood – 31–60 deg. Accordingly, with the maximum speed (0.081 m/s), the optimal wall inclination angles: for metal – 19–31 deg., plastic – 23–37 deg., and wood – 26–44 deg.
Table 4. Optimal storage and transportation facilities wall inclination angles of wheat straw chopped in a drum chopper Maral-125 and milled in the mill Retsch SM 200

<table>
<thead>
<tr>
<th>Material of walls (sliding surface)</th>
<th>Mass movement speed $v$, m/s</th>
<th>Tilt angle of walls $\alpha$ (degrees) while acting of normal pressure force</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 N</td>
<td>11 N</td>
</tr>
<tr>
<td>Metal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.022</td>
<td>37.6</td>
<td>25.2</td>
</tr>
<tr>
<td>0.038</td>
<td>33.4</td>
<td>24.1</td>
</tr>
<tr>
<td>0.054</td>
<td>30.2</td>
<td>23.6</td>
</tr>
<tr>
<td>0.068</td>
<td>30.2</td>
<td>23.3</td>
</tr>
<tr>
<td>0.081</td>
<td>30.6</td>
<td>22.0</td>
</tr>
<tr>
<td>Plastic</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.022</td>
<td>48.3</td>
<td>32.2</td>
</tr>
<tr>
<td>0.038</td>
<td>43.8</td>
<td>32.0</td>
</tr>
<tr>
<td>0.054</td>
<td>40.3</td>
<td>30.4</td>
</tr>
<tr>
<td>0.068</td>
<td>37.1</td>
<td>31.5</td>
</tr>
<tr>
<td>0.081</td>
<td>36.9</td>
<td>31.1</td>
</tr>
<tr>
<td>Wood</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.022</td>
<td>59.7</td>
<td>42.3</td>
</tr>
<tr>
<td>0.038</td>
<td>57.8</td>
<td>41.9</td>
</tr>
<tr>
<td>0.054</td>
<td>53.2</td>
<td>41.3</td>
</tr>
<tr>
<td>0.068</td>
<td>50.0</td>
<td>40.3</td>
</tr>
<tr>
<td>0.081</td>
<td>44.1</td>
<td>36.9</td>
</tr>
</tbody>
</table>

It was found that the increase of supply mass of winter wheat straw chaff to the mill differently affects work performance and energy consumption of the mill (Table 5).

Table 5. Productivity and energy consumption of the mill Retsch SM 200 while milling wheat straw chaff

<table>
<thead>
<tr>
<th>Indexes</th>
<th>Straw chaff quantity supply to the mill</th>
<th>Index increase (%), when increased supply of mass of wheat straw chaff to the mill (from 25g to 75g)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>25 g</td>
<td>50 g</td>
</tr>
<tr>
<td>Labour productivity, kg/h</td>
<td>4.9±0.9</td>
<td>7.4±0.7</td>
</tr>
<tr>
<td>Energy consumption, W·h</td>
<td>1.1±0.2</td>
<td>1.7±0.6</td>
</tr>
</tbody>
</table>

Having increased supply of mass of wheat straw chaff to the mill (from 25g to 75g), energy consumption for milling of straw increased about three times (273%), and mill productivity – only about two times (204%).

Conclusions

The physical-mechanical properties of winter wheat straw and other raw materials are important for the harvesting of these materials, storage, transportation logistics, conversion technology and the selection of equipment and operation.

While preparing straw for production of synthetic diesel fuel, it needs to be chopped and then milled. However, it is not required to dry it. The determined moisture content of the raw material was 12.19 ± 2.05%, bulk density – 0.1300 ± 0.013 g/cm$^3$, density of dry materials – 0.1140 ± 0.013 g/cm$^3$.

During separate stages of wheat straw preparation for synthetic diesel fuel production, their fineness (fractional composition) differs significantly. There were larger than 2 mm particles 69.3 ± 2.63% chopped by a drum chopper; meanwhile, the number of larger than 2 mm particles of the milled wheat straw was only 7.36 ± 1.85%. Dust in the researched variants made 4.02 ± 1.17% and 7.83 ± 1.52% accordingly.

With the increase of wheat straw chaff load from 1 to 31 N, and the speed from 0.022 to 0.081 m/s, the coefficient of dynamic friction and the optimal raw material storage and transportation facilities inclination angles of the walls decreases respectively.

Flow angles of the analyzed raw materials used for production of synthetic diesel slightly differed: natural slope angle of the wheat straw chopped by a drum chopper was 33 ± 11 deg., and that of the wheat straw milled in the mill was 31 ± 13 deg. Fall angle was 82 ± 11 deg. and 73 ± 12 deg. respectively.

It was found that the increase of supply mass of wheat straw chaff to the mill differently affects work performance and energy consumption of the mill. Having increased supply of mass of wheat straw chaff to the mill from 25 g to 75 g, or having increased the supply mass three times, energy consumption for milling of straw increased about three times (273%), and mill productivity – only about two times (204%).
References


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II. Multifunctional Approach to Sustainable Use of Natural Resources
Influence of Meteorological Factors on the Phenological Phases of Ephemeroids

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Aleksandras Stulginskis University, Lithuania

Abstract

In the life of live nature certain rhythms are observed - each year plants begin their vegetative growth, followed by flowering, ripening of fruit, then leaves start to yellow and drop, and the plants undergo dormancy. However, depending on meteorological factors, each year calendar dates of seasonal events considerably differ. The aim of the study - to determine the influence of meteorological factors on phenological phases of ephemeroids in Kamša botanical-zoological reserve. As the research object was chosen a deciduous forest in Kamša botanical-zoological reserve. Research of phenological phases was conducted in 1991, 2000, 2006-2013. During the growing season, ephemeroids were recorded once a week: their height, projection coverage and phenological phases were recorded. To find out what meteorological factors had the greatest influence on phenological phases of ephemeroids, a multiple statistical method – principal component analysis was applied.

Studies show that among meteorological factors the greatest influence on Anemone nemorosa L. had soil surface temperature, while the least – the amount of rainfall and air temperature. Corydalis solida L. was mainly affected by temperature on the soil surface and at 20 cm depth, air temperature, the amount of precipitation. Ficaria verna Huds was influenced by air temperature, but was not affected by the amount of precipitation, soil temperature at a depth of 20 cm, temperature on the surface of the soil. Gagea lutea L. was mainly affected by temperature on the soil surface and at 20 cm depth, air temperature, but was not affected by the amount of precipitation.

Introduction

Plant growth rates, flowering, fruiting periods, duration of vegetation depend on climate conditions. This is expressed by both prolongation of the growing season and changes in the dates of phenological phases of plants, as well as other changes in plant communities (Ahas, 1999; Bogaert et al., 2002; Bradley et al., 1999; Harrington et al., 1999; Root et al., 2003). Phenological observations include all known and most visible phenomena, revealing the seasonality of live nature. Although phenological changes may differ depending on the species and geographic location, abundant observations show that at the end of the twentieth century due to global warming the dates of phenological phases of spring and summer flowering plants have become much earlier, while the dates of autumn phenological phases tended to be delayed, prolonging the growing season of plants (Cleland et al., 2007; Luo et al., 2006; Menzel, 2003; Parmesan 2006; Peñuelas et al., 2009; Peñuelas and Filella, 2001; Romanovskaja 2004; Tucker et al., 2001).

In recent years, due to climate change much attention is paid to plant phenology, searching for the link between climate change and phenological phases. The cycle of plant seasonal rhythm is a good indicator capable of providing knowledge on climate change (Chmielewski and Rötzler, 2002, 2001; Donnelly et al., 2011; Galán et al., 2005; Luch et al., 2002; Parmesan and Yohei, 2003; Schwartz, 1994, 2003; Walther et al., 2002; Zhang et al., 2004).

The research object - broadleaf deciduous forest in Kamša botanical-zoological reserve. Kamša botanical-zoological reserve is located in the territory of Kaunas district municipality, 7 km west of Kaunas, between Marvelė and the Academy, on the left bank of the Nemunas. The reserve was established on the initiative of prof. T. Ivanauskas on September 27, 1960 in Ringaudai to preserve rare animals and plants and their habitats in the forests of the Nemunas valley. The total area of the reserve comprises 321 hectares (Vasiliauskas et al., 1999).

According to climatic classification, the territory lies within the Lithuanian Central lowland climatic region in the subregion of the Nemunas River (Bukantis, 1994). The average annual rainfall comprises about 620-670 mm. During the warm season (from April till October) precipitation amounts to 430-450 mm, while in the cold (November to March) period - 190-220 mm (Lithuanian Climate Guide, 1991). The average annual air temperature is 6.3 °C, average temperature of the coldest (January) month -5.2 °C, that of the warmest (July) month +16.9 °C (Lithuanian Climate Guide, 1992).


The aim of the study - to determine the influence of meteorological factors on the phenological phases of ephemeroids in Kamša botanical-zoological reserve.
Material and methods

Phenological observations of ephemeroids, used for the study, were carried out in 1991 (Prof. dr. V. Marozas) in 2000 (MS M.Mikalauskaitė), and in 2006-2013 (Dr. J.Abraitienė) in Kamša botanical-zoological reserve.

For the study of phenological phases of ephemeroids, permanent research plots (ten 1 x 1 m size plots) were selected. The plots were selected at random, square in shape. They were marked with wooden stakes. Studies were carried out during the growing season (March-July). During the growing season, once a week were recorded ephemeroid species occurring in the plot: their height, projection coverage and phenological stages were determined. In the spring, to determine the height of growing plants, at three specimens of each species were chosen and measured. Later, average height of each species was calculated. Projection coverage was assessed visually. It was determined what surface area (percentage) is covered by each species of herbaceous plants. The following phenological stages of herbaceous plants were recorded: beginning of growth (BG), butonization (B), flowering (F), fruit ripening (MF), seed dispersal (SD), vegetation after flowering (VF), end of the growing season (EG) (Natkevičaitė-Ivanauskienė, 1983). The date of the beginning of each phenological stage was accurately recorded, indicating the month and the day. By further calculations observation dates were converted to days from the beginning of the year.

To find out what meteorological factors have the greatest influence on the phenological stages of ephemeroids, multiple statistical method - principal component analysis was used. For the analysis, the following meteorological factors were taken: air temperature, the amount of rainfall, temperature on the soil surface and at the depth of 20 cm. The influence of meteorological factors on phenological phases was analyzed in four periods: five, ten, fifteen, twenty days before the start of the phenological phase. The data of phenological observations were statistically estimated: average dates of phenological phases, mean error, maximum and minimum values, standard deviation and the coefficient of variation were calculated.

Data evaluation was based on descriptive statistical analysis, correlation analysis and principal component analysis. Correlation analysis was applied to estimate the influence of a certain meteorological factor on the phenological phase. Multiple statistical method - principal component analysis (PCA) was applied as well. By this analysis we assessed the size of influence of meteorological factors on phenological phases. For data analysis, software packages ‘MS Excel – 2007’, ‘STATISTICS 8.0.’ were used.

Results

Ephemeroids are plants of short vegetation, flowering and producing fruit in a very short growing season, followed by their decline. For the beginning of the growing season of Anemone nemorosa L., significant influence had the amount of rainfall in February ($r = -0.97$, $p = 0.04$), while other meteorological factors had no influence ($p>0.05$) (Figure 1). The beginning of vegetation of Anemone nemorosa L., depending on meteorological factors, was on 85-105 d. (Table 1). Flower bud development was mainly influenced by the temperature on soil surface five days before the phase ($r = 0.95$, $p = .01$). On average, flower bud development was on 7 April (97 d.).

![Figure 1. PCA of Anemone nemorosa L. phenological phases and meteorological factors](image_url)
BG – beginning of growth, B – butonization, F – flowering, MF – maturing of fruits, SD – seed dispersal, GF – growth after flowering, EG – end of growth, Hmax – height maximum, Pmax – projection coverage maximum, T02 – temperature in February, T03 – temperature in March, T04 – temperature in April, T05 – temperature in May, T06 – temperature in June, T07 – temperature in July, R02 – amount of rainfall in February, R03 – amount of rainfall in March, R04 – amount of rainfall in April, R05 – amount of rainfall in May, R06 – amount of rainfall in June, R07 – amount of rainfall in July, BGSS15 – temperature on soil surface over fifteen days prior to the onset of the growing period, BSS20 – soil temperature at the depth of 20 cm over twenty days prior to the onset of butonization phase, BSS5 – temperature on soil surface over five days prior to the onset of butonization phase, FST10 – soil temperature at the depth of 20 cm over ten days prior to the onset of flowering phase, FSS5 – temperature on soil surface over five days prior to the onset of flowering phase, MFAT10 – air temperature over ten days prior to the onset of fruit ripening phase, MFST10 – soil temperature at the depth of 20 cm over ten days prior to the onset of fruit ripening phase, MFSS15 – temperature on soil surface over fifteen days prior to the onset of fruit ripening phase, SDAT15 – air temperature over fifteen days prior to the onset of seed dispersal phase, SDAT20 – air temperature over twenty days prior to the onset of seed dispersal phase, SDST20 – soil temperature at the depth of 20 cm over twenty days until the date of seed dispersal phase, GFSS15 – temperature on soil surface over fifteen days prior to the onset of flowering after flowering, EG15 – air temperature over five days prior to the end of the growing period, EGSS20 – temperature on soil surface over twenty days prior to the end of the growing period, HmaxSS5 – soil surface temperature over five days until the date of height maximum, HmaxST20 – soil temperature at the depth of 20 cm over twenty days until the date of height maximum, HmaxAR10 – amount of rainfall over ten days until the date of height maximum, PmaxAT10 – air temperature over ten days until the date of projection coverage maximum, PmaxSS20 – soil surface temperature over twenty days until the date of the projection coverage maximum.

No significant influence of meteorological factors on the flowering phase was ascertained (p > .05). *Anemone nemorosa* L. on average starts flowering on 10 April (100 d.). The earliest flowering of *Anemone nemorosa* L. was recorded on 29 March 2007 (88 d.), the latest - on 26 April 2013 (116 d.). In March 2007 air temperature was by 5.6 °C higher than the climate norm (CN), in March 2013 temperature was by 3.3 °C lower than CN, in April the temperature was close to the CN.

Fruit ripening took place on an average on 4 May (124 d.). In some years, depending on the weather, fruit ripening was on 117-132 d. Seed dispersal was significantly influenced by soil temperature (r = -0.94, p = 0.05) at a depth of 20 cm twenty days prior to the phase. At low temperature seed dispersal was earlier. The lowest soil temperature (10.7 °C) at a depth of 20 cm within twenty days was in 2008. In the same year seed dispersal phase was at the earliest (May 5).

Vegetation after flowering took place on 141-187 d, on average on 162 d. (June 11). The earliest vegetation after flowering was on 21 May 2008, the latest - 6 July 2008. The end of the vegetation of *Anemone nemorosa* L. was significantly influenced by soil temperature (r = -0.97, p = 0.03) twenty days to the phase, and soil temperature (r = -0.98, p = 0.01) at 20 cm depth five days before the phase. The lowest soil temperature (15.4 °C) at a depth of 20 cm was in 1991. In the same year the growing season of *Anemone nemorosa* L. was short. On average, growing season of *Anemone nemorosa* L. lasted until July 6 (187 d.).

*Anemone nemorosa* L. used to reach its maximum height on average on 27 April (117 d.). The earliest height peak was attained on 13 April 2009 (103 d), the latest - in 2000 and on 9 May 2006 (129 d.). A statistically significant relationship was established between the height maximum and the amount of precipitation ten days before the peak (r = -0.96, p = 0.01). A reliable relationship was ascertained between the projection coverage maximum and air temperature (ten days before the peak) (r = 0.94, p = 0.05). Projection coverage maximum by *Anemone nemorosa* L. at the latest was reached on 9 May 2000 (129 d.), the earliest – on 15 April 2008 (105 d.), averagely – on 23 April (113 d.).

**Table 1.** *Anemone nemorosa* L. Characteristics of phenological phases, maximal height and projection coverage dispersion

<table>
<thead>
<tr>
<th><em>Anemone nemorosa</em> L.</th>
<th>Days from the beginning of the year</th>
<th>Standard deviation</th>
<th>Variation coefficient percent</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mean ± error</td>
<td>minimal value</td>
<td>maximal value</td>
</tr>
<tr>
<td>Beginning of growth</td>
<td>92 ± 3.7</td>
<td>85</td>
<td>105</td>
</tr>
<tr>
<td>Butonization</td>
<td>97 ± 3.1</td>
<td>85</td>
<td>104</td>
</tr>
<tr>
<td>Flowering</td>
<td>99 ± 3.1</td>
<td>88</td>
<td>111</td>
</tr>
<tr>
<td>Fruit ripening</td>
<td>124 ± 1.7</td>
<td>117</td>
<td>132</td>
</tr>
<tr>
<td>Seed dispersal</td>
<td>139 ± 3.9</td>
<td>125</td>
<td>156</td>
</tr>
<tr>
<td>Growth after flowering</td>
<td>162 ± 5.4</td>
<td>141</td>
<td>187</td>
</tr>
<tr>
<td>End of vegetation</td>
<td>188 ± 6.5</td>
<td>156</td>
<td>209</td>
</tr>
<tr>
<td>Height max</td>
<td>117 ± 3.4</td>
<td>103</td>
<td>129</td>
</tr>
<tr>
<td>Projection coverage max</td>
<td>113 ± 2.9</td>
<td>105</td>
<td>129</td>
</tr>
</tbody>
</table>

On average, *Corydalis solida* L. vegetation begins on 4 April (95 ± 3.5) (Table 2). It was found that the beginning of growth was significantly influenced by soil surface temperature (r = 0.92, p = 0.03) ten days prior to the phase, air temperature (r = -0.97, p = 0.02) five days before the period and the amount of precipitation (r = 0.98, p = 0.01) five days before the period (Figure 2). The earliest *Corydalis solida* L. vegetation began on 29 March 2007 (88 d.), when the soil surface temperature was the highest (8.3 °C) during the study period.

Butonization was significantly influenced by meteorological factors twenty days prior to the phase, i.e. soil temperature (r = -0.95, p = 0.02) at a depth of 20 cm and amount of rainfall (r = 0.97, p = 0.01). The latest flower bud
development of *Corydalis solida* L. was in 2000. In the same year was the smallest amount of precipitation (7.4 mm) and high soil temperature (4.9 °C) at a depth of 20 cm. Flowering of *Corydalis solida* L. on average was on 10 April (100 ± 3.5). This was influenced by soil temperature ($r = -0.96$, $p = 0.03$) at a depth of 20 cm ten days prior to the phase. No significant relationship was found between the flowering of *Corydalis solida* L., the sum of active temperatures and hydrothermal coefficient ($p> 0.05$).

It was found that fruit ripening was influenced by soil surface ($r = 0.95$, $p = 0.04$) temperature fifteen days prior to the phase, soil temperature ($r = 0.97$, $p = 0.05$) at 20 cm depth the ten days prior to the phase and amount of rainfall ($r = 0.97$, $p = 0.05$) in April. In April 2010 fell a large amount of precipitation (58 mm). In the same year fruit ripening phase started the earliest.

The earliest seed dispersal was on 2 May, the latest - on 6 June. Seed dispersal was affected by air temperature ($r = 0.93$, $p = 0.02$) fifteen days prior to the phase. Statistically significant relationship was not found between growth after flowering, the end of the growing season and meteorological factors ($p> 0.05$).

Statistically significant relationship was ascertained between height maximum of *Corydalis solida* L., temperature on the soil surface ($r = -0.94$, $p = 0.03$) five days before the date of the peak, and soil temperature ($r = -0.96$, $p = 0.02$) at 20 cm depth twenty days before the date of the maximum. In 2010 soil temperature (3.0 °C) at a depth of 20 cm was the lowest. In the same year *Corydalis solida* L. reached its height maximum at the earliest (99 d.).

Projection coverage maximum *Corydalis solida* L. reached at the earliest on 5 April (95 d.), while the latest – on 6 May (126 d.). The influence of meteorological factors on the projection coverage maximum was not observed.

### Table 2. *Corydalis solida* L. Characteristics of phenological phases, maximal height and projection coverage dispersion

<table>
<thead>
<tr>
<th><em>Corydalis solida</em> L.</th>
<th>Days from the beginning of the year</th>
<th>Standard deviation</th>
<th>Variation coefficient percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beginning of growth</td>
<td>95 ± 3.5</td>
<td>5.7</td>
<td>5.9</td>
</tr>
<tr>
<td>Butonization</td>
<td>97 ± 3.8</td>
<td>9.7</td>
<td>10.1</td>
</tr>
<tr>
<td>Flowering</td>
<td>100 ± 3.5</td>
<td>9.5</td>
<td>9.4</td>
</tr>
<tr>
<td>Fruit ripening</td>
<td>120 ± 3.5</td>
<td>8.9</td>
<td>7.5</td>
</tr>
<tr>
<td>Seed dispersal</td>
<td>128 ± 3.8</td>
<td>10.3</td>
<td>8.0</td>
</tr>
<tr>
<td>Growth after flowering</td>
<td>139 ± 3.5</td>
<td>9.7</td>
<td>6.9</td>
</tr>
<tr>
<td>End of vegetation</td>
<td>159 ± 6.4</td>
<td>16.2</td>
<td>10.1</td>
</tr>
<tr>
<td>Height max</td>
<td>115 ± 3.9</td>
<td>11.2</td>
<td>9.7</td>
</tr>
<tr>
<td>Projection coverage max</td>
<td>105 ± 2.9</td>
<td>8.4</td>
<td>8.0</td>
</tr>
</tbody>
</table>

Beginning of the vegetation of *Ficaria verna* Huds was earlier when the amount of rainfall in February was lower (Fig. 3). Statistically significant relationships were found between the beginning of vegetation and the amount of rainfall in February ($r = -0.92$, $p = 0.05$). A significant reliability was established between *Ficaria verna* Huds phenological phases ($p<0.05$). On average, flower bud development was held on April 10 (Table 3).
The earliest flower bud development was on 26 March 2008 (85 d), the latest - on 28 April 2006 (118 d). Depending on the meteorological factors, Ficaria verna Huds blossomed on 89-125 d. The end of the vegetation period was significantly affected by air temperature five days before the phase (r = -0.98, p = 0.01). In 2008 the growing season of Ficaria verna Huds was short. This was influenced by low temperature five days before the end of the growing season (11.9 °C). Among the phenological phases and monthly temperatures, the temperature on the soil surface and at 20 cm depth no statistically significant relationship (p> .05) was ascertained.

Table 3. *Ficaria verna* Huds Characteristics of phenological phases, maximal height and projection coverage dispersion

<table>
<thead>
<tr>
<th>Ficaria verna Huds</th>
<th>Days from the beginning of the year</th>
<th>Standard deviation</th>
<th>Variation coefficient percent</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mean ± error</td>
<td>minimal value</td>
<td>maximal value</td>
</tr>
<tr>
<td>Beginning of growth</td>
<td>92 ± 4.9</td>
<td>85</td>
<td>111</td>
</tr>
<tr>
<td>Butonization</td>
<td>100 ± 5.4</td>
<td>85</td>
<td>118</td>
</tr>
<tr>
<td>Flowering</td>
<td>105 ± 5.4</td>
<td>89</td>
<td>125</td>
</tr>
<tr>
<td>Fruit ripening</td>
<td>125 ± 3.5</td>
<td>110</td>
<td>136</td>
</tr>
<tr>
<td>Seed dispersal</td>
<td>135 ± 4.1</td>
<td>117</td>
<td>150</td>
</tr>
<tr>
<td>Growth after flowering</td>
<td>147 ± 3.4</td>
<td>133</td>
<td>157</td>
</tr>
<tr>
<td>End of vegetation</td>
<td>159 ± 3.2</td>
<td>142</td>
<td>167</td>
</tr>
<tr>
<td>Height max</td>
<td>116 ± 4.9</td>
<td>97</td>
<td>137</td>
</tr>
<tr>
<td>Projection coverage max</td>
<td>112 ± 3.8</td>
<td>97</td>
<td>123</td>
</tr>
</tbody>
</table>

Figure 3. *PCA of Ficaria verna* Huds phenological phases and meteorological factors (see explanation in Fig.1)

The beginning of vegetation of *Gagea lutea* L. strongly correlates with bud formation (r = 0.89, p = 0.03), flowering (r = 0.77, p = .04). The earliest beginning of vegetation (85 d.), bud formation (93 d.) and flowering (98 d.) was in 2008 (Table 4). It was found that the beginning of vegetation was significantly affected by the temperatures on soil surface (r = -0.88, p = 0.02) (Fig. 4) fifteen days prior to the phase. Bud formation was not significantly affected by meteorological factors (p> 0.05). Flowering was influenced by temperatures on the soil surface (r = 0.95, p = 0.01) and at 20 cm depth (r = 0.92, p = 0.01) five days before the phase.

Statistically significant relationships were found between air temperature, fruit ripening (ten days prior to the phase) (r = 0.85, p = 0.03) of *Gagea lutea* L. and seed dispersal (twenty days prior to the phase) (r = 0.81, p =0 .04). The earliest seeds dispersal phase was on 5 May 2009 (125 d.), when twenty days prior to the phase air temperature was 10.1 °C. No statistically significant relationship was found between vegetative growth after flowering, the end of vegetation and meteorological factors (p> 0.05).

It was found that maximum projection coverage was significantly influenced by the temperature on the soil surface (r = -0.82, p = 0.04) and at 20 cm depth (r = -0.92, p = 0.01) twenty days prior to the phase. Projection coverage maximum *Gagea lutea* L. reached at the latest on 30 April 2013 (120 d), the earliest – on 27 March 1991 (86 d.). No statistically significant relationship between the phases of common *Gagea lutea* L. and the amount of precipitation (p> 0.05) was ascertained.
### Table 4. *Gagea lutea* L. Characteristics of phenological phases, maximal height and projection coverage dispersion

<table>
<thead>
<tr>
<th>Phenological Phase</th>
<th>Days from the beginning of the year</th>
<th>Standard Deviation</th>
<th>Variation Coefficient Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beginning of growth</td>
<td>90 ± 1.6</td>
<td>5,4</td>
<td>6,0</td>
</tr>
<tr>
<td>Butonization</td>
<td>97 ± 1.7</td>
<td>6,5</td>
<td>6,7</td>
</tr>
<tr>
<td>Flowering</td>
<td>104 ± 1,9</td>
<td>6,3</td>
<td>6,0</td>
</tr>
<tr>
<td>Seed dispersal</td>
<td>122 ± 1,9</td>
<td>5,5</td>
<td>4,5</td>
</tr>
<tr>
<td>Growth after flowering</td>
<td>132 ± 2,5</td>
<td>7,1</td>
<td>5,3</td>
</tr>
<tr>
<td>End of vegetation</td>
<td>155 ± 4,1</td>
<td>10,9</td>
<td>7,0</td>
</tr>
<tr>
<td>Height max</td>
<td>116 ± 1,3</td>
<td>3,4</td>
<td>2,9</td>
</tr>
<tr>
<td>Projection coverage max</td>
<td>98 ± 3,4</td>
<td>9,1</td>
<td>9,3</td>
</tr>
</tbody>
</table>

**Figure 4. PCA *Gagea lutea* L. phenological phases and meteorological factors (see explanation in Fig.1)**

**Conclusions**

Summarizing the influence of meteorological factors on ephemeroids, it can be stated that the beginning of the growing season was mainly influenced by the soil surface temperature, the amount of rainfall, air temperature, while soil temperature at a depth of 20 cm had no effect. Butonization phase was mainly influenced by the amount of rainfall, temperature on the soil surface and at 20 cm depth, while air temperature had no effect. Flowering phase was mainly affected by soil temperature at a depth of 20 cm, temperature on the surface of the soil, while air temperature and the amount of rainfall had no effect. Fruit ripening phase was influenced by air temperature, temperature on the soil surface and at 20 cm depth, but the amount of precipitation did not affect this phase. Seed dispersal phase was influenced by air temperature, soil temperature at 20 cm depth, amount of rainfall, but temperature on the surface of the soil had no effect. The phase of vegetation after flowering was influenced by soil surface temperature, soil temperature at a depth of 20 cm, air temperature, except rainfall. The phase of the end of vegetation was influenced by temperature on the soil surface and at 20 cm depth, air temperature, while the amount of rainfall did not affect it.

Height maximum was mainly influenced by the temperature on the soil surface and at 20 cm depth, amount of rainfall, while air temperature had no effect. Projection coverage maximum was mainly affected by temperature on the soil surface and at 20 cm depth, air temperature, but was not affected by the amount of precipitation. Among meteorological factors, the greatest impact on ephemeroids had the temperature of the soil surface and at 20 cm depth, while the least impact – the amount of precipitation and air temperature.

**References**


Visual Impact Assessment of Wind Turbines and their Farms on Landscape of South-Western Lithuania (Tauragė, Pagėgiai Regions)

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Abstract

Until 2013, as many as 125 major wind turbines (over 350 kW) were built in Lithuania. The biggest number of wind turbines are constructed in Kėdainiai (58 units), Šilutė (33 units) and Tauragė (33 units) regions. The wind farms, built in Tauragė district, are located adjacent to Pagėgiai district, thus the visual impact on the district roadscape is felt as well. Visual impact of wind farms located in Tauragė and Pagėgiai regions is analyzed in the paper. In seeking to assess the impact of wind turbines based in Tauragė and Pagėgiai regions on the landscape and the villages, the analysis of cartography material was carried out and the inventory of all wind turbines was made (GIS data base). On assessing the importance of the roads with regard to the intensity of traffic and tourist flows, the observation places were established and photo fixation was performed. The impact was assessed from eleven observation places (all the places were close to the roads). During the study, the nature, importance and degree of contrast of the visual impact of wind turbines were assessed. In assessing the visual impact of wind turbines on the landscape, it was found that woodlands and villages make a significant impact on the visibility of turbines. The wind turbines seen on the axis of the road perspective are not only observed for some length of time, but often serve as a landmark.

Introduction

In Lithuania, until the year 2013, wind turbines of 250 MW total capacity were planned to be built. At the beginning of 2013, the total capacity of wind turbines was 220 MW. Until 2013, as many as 125 major wind turbines (over 350 kW) were built in Lithuania. The total number of turbines (including minor ones) amounts to 200 units. The biggest number of wind turbines are constructed in Kėdainiai (58 units), Šilutė (33 units) and Tauragė (33 units) regions (The European Wind Energy Association, 2012; LITGRID, 2013). Three wind farms, built in Tauragė district, are located adjacent to Pagėgiai district, thus the visual impact on the district roadscape is felt as well (Fig. 1).

The aim of the paper is to make an inventory of wind farms and single wind turbines in Tauragė and Pagėgiai regions, to discuss visual significance of wind turbines and contrast-determining factors as well as to evaluate the impact of the turbines on the landscape when observing them from the selected observation place.

The visual impact on the roadscape was assessed from eleven selected observation places. The location of the places was chosen in accordance with the road categories: one place has been chosen near the main highway Klaipėda - Kaunas (No. A1), five places - near the main highway Pagėgiai - Tauragė (No. A12), two places - near the national roads Tauragė - Žygaičiai (No. 199) and Pagėgiai - Vilkyškiai (No. 141), and three places – near the regional roads. (Fig. 2). The study in situ was performed on May 3-4, 2013. The day was sunny, hardly cloudy and the visibility of the turbines was excellent.

Visibility of wind turbines is different when observing them in a static or a dynamic state. While observing them from a static position, the picture of the turbine does not change with time. But when studying the movement of transport and in a dynamic position of the observer, a visual relation between wind turbines and the landscape changes permanently. The sight may be partially limited by physical possibilities (e.g. the size of the car window) to observe the turbines from the inside of the vehicle (Homewood, 2011).

According to the values of the zones of the visual impact of wind turbines determined by the authors of the paper, the major turbines, the blade-tip height of which amounts to 120 – 150 m, can be visible at a distance of up to 30 km (for clear visibility). The following intervals of zones of visual influence are recommended: 0-1 km; 1-3 km; 3-5 km; 5-7 km; 7-10 km; 10-13 km; 13-16 km; 16-20 km; >20 km. At a distance of 0-3 km wind turbines usually dominate in landscape, at a distance of 3-7 km – they become accents, at a distance of 7-10 km – subdominants and at a distance of >10 km – background elements (Kamičaitė-Vertaišienė, Abromas, 2012; University of Newcastle, 2002; Jalloul, Moreau, 2009).

In carrying out the assessment of the impact of wind turbines on the landscape, the principles of forming the contrast of the objects and the surrounding environment “Bureau of Land Management” (USA) were used:

1. the components and elements forming the contrast are determined;
2. the contrast may be nonexistent, weak, medium or strong;
3. the contrast is nonexistent, when not seen or perceived;
4. a weak contrast is when it is visible , however, does not attract attention;
5. a medium contrast attracts attention and starts dominating in the landscape;
6. a strong contrast is dominating in the landscape and attracts attention (Bureau of Land Management, 2012).

The wind turbines have a visual effect on the landscape at a distance of up to 15-20 km (background elements of the landscape). However, when observing the turbines from the roads (in this case from a dynamic position), the turbines situated nearer the road produce a significantly bigger effect. The turbines situated farther from the observer (10-20 km), make an impact on the landscape only when they are visible on the axis of the road perspective. Apart from the roads, where the turbines are clearly visible, not only intensive traffic roads, but also auto tourism roads are important (Frantil, Kunc, 2011).
Results of research

From 2006 to 2011, three wind farms were built near Griežpelkiai II and Kreivėnai villages, Tauragė district. The total number of wind turbines is 22 units. All the wind turbines are of the same type (Enercon E-82) but of two different types of towers - steel and reinforced concrete structure. There are 15 steel tower wind turbines (hub height 86 m, blade-tip height 127 m), and seven reinforced concrete tower wind turbines (hub height 109 m, blade-tip height 150 m) (Table 1). The discussed wind farms have the visual impact on some part of Pagėgiai district (they were built near the district). In 2013, a group of small wind turbines (225 kW) was built in the adjacent area (near Aukštvilkiai village), which were set out in the open agrarian area. They are visible while on the road Pagėgiai - Tauragė (No. E77).

The territory is attributed to the sandy plains and mildly undulating landscape according to the general character of the natural landscape. Most of the territory is covered by farmland areas. The visual structure of the territory is formed by slight vertical dispersion (slightly undulating). According to the horizontal separation, some places are characterized by the landscape of dominant open, fully reviewed spaces, and some – by the landscape of semi-open, largely reviewed spaces (Kavaliauskas, 2006). Wind farms, communication towers and overhead power lines dominate as vertical elements. Small forest tracts occur in the territory.

In 2008, two small wind turbines (225 kW), previously exploited in another country, were built in Meldikviršiai village, closest to Tauragė town. The distance to Tauragė town is 7 km. In 2013, a group of four small (Enercon E-40) wind turbines was built in the eastern part of the district, near Batakiai village.

In Pagėgiai district there were built two large wind turbines (2,000 kW), which are 6 km distant from Pagėgiai town, and two small wind turbines (225 kW) (the distance to Pagėgiai town is 2 km.) (Table 1).

Table 1. Wind turbines in Tauragė/ Pagėgiai districts

<table>
<thead>
<tr>
<th>No.</th>
<th>Regulation</th>
<th>Wind turbines in Tauragė/ Pagėgiai districts</th>
<th>Wind turbine type</th>
<th>Number of wind turbines</th>
<th>Power (kW)</th>
<th>Total power (kW)</th>
<th>Installation year</th>
<th>Dimensions of wind turbines (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Hub height</td>
</tr>
<tr>
<td>1</td>
<td>B</td>
<td>WIND turbines</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Meldikviršiai (Užkerteniai)</td>
<td>Darwin 27/225</td>
<td>2</td>
<td>225</td>
<td>450</td>
<td>2008</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Griežpelkiai II (Užkerteniai)</td>
<td>Enercon E-40</td>
<td>1</td>
<td>250</td>
<td>250</td>
<td>2012</td>
<td>65</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Aukštvilkiai</td>
<td>Vestas WD34</td>
<td>3</td>
<td>225</td>
<td>675</td>
<td>2013</td>
<td>30</td>
</tr>
<tr>
<td>2</td>
<td>B</td>
<td>Single group wind turbines</td>
<td>Paprūdžiai</td>
<td>1</td>
<td>250</td>
<td>250</td>
<td>2013</td>
<td>65</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Enercon E-33</td>
<td>1</td>
<td>250</td>
<td>250</td>
<td>2012</td>
<td>50</td>
</tr>
<tr>
<td>3</td>
<td>B</td>
<td></td>
<td>Endriškiai</td>
<td>2</td>
<td>225</td>
<td>450</td>
<td>2008</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Darwin 27/225</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>B</td>
<td></td>
<td>Anužiai</td>
<td>2</td>
<td>2000</td>
<td>4000</td>
<td>2008</td>
<td>86</td>
</tr>
</tbody>
</table>

In assessing the impact of wind turbines on the landscape it is essential to find how the observed landscape is seen, i.e. from a static or a dynamic position of the observer. In this respect the roadscape observed from a dynamic position is important.

The factors considered in determining the degree of contrast:

- Distance: the bigger the distance, the weaker is the perceived contrast. For a smaller distance, the wind turbines look dominating in the landscape. For a bigger distance, the impact becomes less significant.
- Observation time: the longer the turbines are observed, the stronger is the visual impact.
- Relative size or scale: visual impact is directly dependent on the size and scale of the object. The relative size of wind turbines in the landscape is described by three main parameters: hub height, blade-tip height and rotor diameter (Environmental Resources Management, 2009).
- Observation season: in determining the contrast, physical conditions of the period of the most intensive visual usage must be evaluated. The visibility of wind turbines is differently affected by winter season. Since the tower and the rotor of almost all the turbines are of a white or grey colour, they merge with the colour of the environment (Cialdea et al., 2010).
- Illumination conditions: while visibility in the daylight is the best, it is worsened when getting dark. At night time only the signal lights of the turbines are visible.
- Spatial relations: since wind turbines are dominating in the landscape due to their big height, they simultaneously become a vertical landmark. The cumulative impact (of several turbines or farms) is also possible.
• Atmospheric conditions: at differing weather conditions, different contrast between the turbine and the sky background is formed. For cloudy conditions, wind turbines are less visible. In some cases, the turbine blades can be absolutely invisible against a cloudy background.

• Movement: the movement in the landscape attracts attention and increases contrast. It is important when observing the wind turbines, since the rotor is a dynamic element. The rotor in movement attracts attention, especially when the turbine is visible on the perspective axis of the road (Bureau of Land Management 2001; Tsoutsos et al., 2010).

Table 2. Assessment of the significance of visual impact of wind turbines and the degree of contrast as well as the nature of the impact from the observation places (due to a large scope of study, the assessment results in the paper are presented from six observation places only).

<table>
<thead>
<tr>
<th>No., road and observation place</th>
<th>Visually influenced villages</th>
<th>Distance to the wind turbines (km)</th>
<th>Nature of visual impact</th>
<th>Visual significance (VS) and contrast degree (CD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Klaipėda - Kaunas (No. A1). From Kryžkalnis viaduct</td>
<td>Paprūdžiai</td>
<td>1,5</td>
<td>A single wind turbine is visible on the hilly agrarian landscape on the right side of the main highway Klaipėda - Kaunas (No. A1). The wind turbine becomes a landscape accent/subdominant due to the overhead power lines and relief that are close to the observer. The visual impact is positive.</td>
<td>Falls into the level of visual accents/subdominants (VS). Medium (due to relative size and relief) (CD)</td>
</tr>
<tr>
<td>2. Taurage - Žygaičiai</td>
<td>Kęsčiai</td>
<td>1,3</td>
<td>Two small wind turbines (225 kW) are fully visible on the flat landscape on the right side of the road. They are Wind turbines are perceived as landscape</td>
<td></td>
</tr>
</tbody>
</table>

Figure 1. Locations of wind turbines, their farms (WT farms) and viewing points (author of the map: J. Abromas, 2013)
The evaluation found that wind turbines in the roadscape visual space are seen when driving along the main highways, national and regional roads: Klaipėda – Kaunas (No. A1), Pagėgiai – Tauragė (No. E77), Tauragė – Žygaičiai (No. 199), Pagėgiai – Vilkyškiai (No. 141), Silutė – Pagėgiai (No. 141), Pagėgiai – Natiškiai (No. 4201), Tauragė – Dauglaukis (No. 4506), Meldikviršiškiai – Sartininkai (No. 4502). The roads mentioned are also important as tourist routes. The most significant impact of wind turbines is felt when driving along the main highway Pagėgiai - Tauragė (No. E77). While driving along the mentioned road, three large wind farms are located on both sides of the road. By observing the wind turbines from different observation sites, visual significance include the levels of dominant accents/subdominants. No. 7, No. 8 (on both sides of the road) and No. 10 are the main observation sites, from which the observed wind turbines adversely affect the visual image.

<table>
<thead>
<tr>
<th>Road Segment</th>
<th>Observation Sites</th>
<th>Visual Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pagėgiai - Vilkyškiai (No. 141). By Lumpėnai village</td>
<td>4</td>
<td>Wind farms, seen on the hill, become higher visually. Separate forest tracts and tree groups are also visible within the observation field, which reduce the visual impact of wind turbines. Although the observation distance is quite big, wind turbines become landscape accents.</td>
</tr>
<tr>
<td>Pagėgiai town</td>
<td>6. Pagėgiai - Tauragė (No. E77). Closest to Pagėgiai town</td>
<td>Piktupėnai</td>
</tr>
<tr>
<td></td>
<td>8. Pagėgiai – Tauragė (No. E77). By Vingriai village</td>
<td>Vingriai, Strepeikiai</td>
</tr>
<tr>
<td></td>
<td>9. Pagėgiai - Tauragė (No. E77). By Griežpelkiai village</td>
<td>Griežpelkiai I</td>
</tr>
<tr>
<td></td>
<td>10. Pagėgiai - Tauragė (No. E77). By Lauksargiai village</td>
<td>Lauksargiai</td>
</tr>
<tr>
<td></td>
<td>11. Griežpelkiai I - Natiškiai (No. 4226). By the rail crossing.</td>
<td>Griežpelkiai I</td>
</tr>
</tbody>
</table>

The evaluation found that wind turbines in the roadscape visual space are seen when driving along the main highways, national and regional roads: Klaipėda – Kaunas (No. A1), Pagėgiai – Tauragė (No. E77), Tauragė – Žygaičiai (No. 199), Pagėgiai – Vilkyškiai (No. 141), Silutė – Pagėgiai (No. 141), Pagėgiai – Natiškiai (No. 4201), Tauragė – Dauglaukis (No. 4506), Meldikviršiškiai – Sartininkai (No. 4502). The roads mentioned are also important as part of tourist routes. The most significant impact of wind turbines is felt when driving along the main highway Pagėgiai - Tauragė (No. E77). While driving along the mentioned road, three large wind farms are located on both sides of the road. By observing the wind turbines from different observation sites, visual significance include the levels of dominant accents/subdominants. No. 7, No. 8 (on both sides of the road) and No. 10 are the main observation sites, from which the observed wind turbines adversely affect the visual image.
While driving along Pagėgiai - Tauragė road (No. E77), the impact of wind turbines on the roadscape can be divided into the following:

- Wind farms (due to relief) are started to be seen after leaving Pagėgiai town (the distance to the wind turbines is 7 km).
- The visual impact of wind turbines includes the level of subdominants from Pagėgiai town to Piktupėnai village (distance – 6-7 km).
- Wind turbines generally dominate in the landscape from Piktupėnai village to Vingriai village (distance 3-5.5 km).
- Wind turbines are clearly dominant in the roadscape from Vingriai village to Lauksargiai village (at this road section wind turbines are visible on both sides of the road. The distance of the wind turbines closest to the road is about 150 m).
- Wind turbines are invisible from Lauksargiai village to Tauragė town due to the existing populated areas and relief (the distance to wind turbines – 7-13 km).

During the assessment of the impact, there is a possibility of accumulating impact of wind turbine, when the planned wind farm is being built adjacent to the existing wind farms (Pakalnis, Venckus, 2012). It is important to Tauragė district, where one area includes three wind farms. At present, the territory planning documents are being prepared, and additional wind turbines are planned to be built between Lumpėnai and Vilkyškiai villages.

In assessing the visual effect of wind turbines on the roadscape it was found that more often than not the woodlands and individual big trees make a significant effect on the visibility of turbines (Domingo-Santos et al., 2011; Katsaparakakis, 2012). Minor elements of the landscape (hills, roadside bushes, etc.) near the observer also have some influence on the visibility of turbines. The turbines visible on the road perspective axis are especially important not only because they are within the field of view for a longer period of time, but because they tend to turn into a vertical landmark. It is also important as wind turbines are located of the road. In the road Pagėgiai - Tauragė (No. E77) (at Vingriai village) wind turbines built at right angles to the road (blade-tip height of wind turbines – 150 m) and visually occupy the whole space (Fig. 5). The wind turbines near roads can be partly masked by green barriers, covering thus a lower part of the massive tower. Solitary wind turbines, however, do not make a negative impact on the perspective of a road (Arakawa et al., 2002).
Conclusions

The visual character and aesthetic - visual quality of the landscape is changing mainly due to wind farms and single wind turbines built in the Western Lithuania. 124 wind turbines operate in Kretinga, Šilutė, Tauragė districts alone, and new wind farm projects are being prepared. It is therefore important to evaluate the potential impact of both present and future wind turbines on the landscape.

When driving along the main highway Pagėgiai – Tauragė (No. E77), the visual impact of three wind farms in the surroundings of Griežpelkiai II village can be divided into the zones of background element, subdominant, dominant and highly dominant wind turbines. The zone of strongly dominant wind turbines is further distinguished due to particularly strong predominance of wind turbines (from Virgėiai to Lauksargiai villages). The mentioned predominance is enhanced by the relief, blade-tip height of wind turbines (up to 150 m) and small observation distance. In this section of the road wind turbines built at right angles to the road and visually occupy the whole space.

Wind turbines reduce the aesthetic potential of the roadscape from the observation sites No. 7, 8 and 10. All the observation sites are situated near Pagėgiai – Tauragė road (No. E77). The negative impact is caused by particularly strong predominance of wind farms, as well as natural and anthropogenic environmental elements being put into the shade. The impact of single small wind turbines (up to 350 kW) or their groups, seen from the observation sites, include the level of landscape accents, and in some cases (3, 6 and 11 observation sites) make positive impact on the landscape.

In summarizing the data obtained from different observation places, it was found that most often the landscape is positively affected when visual significance covers the level of accents-background elements. When the landscape is visually/generaly dominated by wind turbines, then the aesthetic potential of the landscape is usually diminished.

References


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The Influence of Management and Conservation on Chemical Properties of Peat Soil

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Abstract
This work aims to understand how to manage and maintain quality of the peat soil considering its chemical properties. The study was carried out on a peat bog (Terric Histosol) with the removed and non-removed peat layer at the former Radviliškis Experimental Station of the Lithuanian Institute of Agriculture. Soil samples for chemical analyses were taken from peat bog soil from 0–10, 10–20 and 20–30 cm layers in 3 replicates in August 2012. The pH of differently used peat soil ranged from 5.5 to 7.5. Non-removed peat bog soil had higher amount of humus compared to peat bog soil with removed peat layer. The soil of fertilized perennial grasses with non-removed peat layer and forest peat bog soil with removed peat layer had higher nitrogen content compared with the other treatments. Renaturalisation is still observed after the usage of the peat soil. There are variations in their chemical composition. The carbon accumulation and higher sustainability potential was established in the soil with non-removed peat layer in which the fertilized perennial grass was cultivated till the termination of the experiment.

Keywords: Terric Histosol, peaty soil, humus, nitrogen, mobile humic substances, C:N, C:P; soil quality.

Introduction
Ecosystems of peat bogs are one of the larger organic carbon reserves. Perennial grasses are believed to be able to reduce organic matter (OM) decomposition, since they partly restore OM by leaving a great content of root and stubble. Some researchers recommended establishing long-term grasslands, which, if properly managed, could produce a high herbage yield (De Visser et al., 2001; Szabo et al., 1999); however OM transformation depends on the composition of individual swards and their management. Natural and agricultural ecosystems not only play an important role in the conversion of atmospheric CO₂ into soil organic matter (SOM), but also in the sequestration of soil organic carbon (SOC) or humus. Humus is the main component of SOM; therefore conversion of natural ecosystems into agricultural lands with intensive cultivation strongly depletes SOC pools. Numerous researchers have investigated the effects of different management practices on SOM composition using chemical, spectroscopic and other methods (Maryganova et al., 2004; Glatzet et al., 2003; Janušienė, Šleinys, 2003). SOM is considered as one of the main indicators of soil fertility, cultivation level and soil resistance to the negative anthropogenic and natural factors; it serves in providing plants with nutrients, adds to their conservation, and determines the soil potential properties. There are numerous findings on the dynamics of SOM status in mineral soils (Glatzet et al., 2003; Janušienė, Šleinys, 2003); however, there are not enough data on the status of SOM in peat bog soils. Less is known about the impact of land-use systems, their changes on accumulation of organic carbon and nitrogen and their ratio. After 12 years since the termination of field experiment the differences in soil chemical composition remained still between treatments of differently used peat soil, particularly in soil with non-removed peat layer.

The main task of this research was to study the chemical composition of the differently used peat soil, to identify the differences in the SOM and nitrogen content, humic substances, C to N and C to P ratios and acidity of Terric Histosol with removed and non-removed peat layer.

Materials and methods
Experimental site and conditions. Field experiments were conducted at the former Radviliškis Experimental Station of the Lithuanian Institute of Agriculture on a peat bog (Terric Histosol) with the removed and non-removed peat layer at an altitude of 120 m above s4ea level (55°45´N, 23°30´E) (Petraitytė et al., 2003). The Radviliškis peat bog eastern edge borders the Radviliškis town (Fig.1), and covers an area of 1203 ha. The Radviliškis bog has formed at the source of the Beržė River. The treatments investigated in the soil with non-removed peat layer: un-used peat soil (treatment 1), earlier unfertilized perennial grasses (treatment 2), crop rotation (potatoes; winter rye; red clover) field (treatment 3); red clover (Trifolium pratense L.) and timothy (Phleum pratense L.) mixture (treatment 4); fertilized with commercial NPK fertilisers perennial grasses (treatment 5). The investigated treatments of peat soil with removed peat layer: forest (treatment 1), arable crop field rotations (treatment 2) and meadow peat soil (treatment 3) (Petraitytė et al., 2003).
Methods of analyses. Soil samples for chemical analyses were taken from the peat bog soil from 0–10, 10–20 and 20–30 cm layers in 3 replicates at the former Radviliškis Experimental Station in August 2012. The soil samples were air-dried, ground, and sieved using a 0.25 mm sieve. Chemical analyses were carried out at the Chemical Research Laboratory of Institute of Agriculture, Lithuanian Research Centre for Agriculture and Forestry. SOM content was determined by the Tyurin method modified by Nikitin and calculated by multiplying $C_{\text{org.}}$ content by 1.724 (Nikitin, 1999). For mobile humic substances determination the extraction procedure was provided using 0.1 M NaOH solution, ratio was 1:5, total N and P – spectrophotometrically with Cary 50 (Varian, Germany) at the wavelength of 590 nm after wet digestion (Šlepetienė et al., 2010).

Statistical analyses. Experimental data were analysed by one-factor analysis of variance (Anova, Statistica, vers. 6.0) (Tarakanovas, Raudonius, 2003).

**Results and discussion**

The rational use of peat soil is aimed to achieve an effective productivity of agricultural crops grown in such soils and maximal organic matter conservation is impossible without the knowledge of OM transformation processes occurring in the soil. Data provided in Figure 2 suggest that the peat bog with the non-removed peat layer contained more humus (SOM) (69.9 – 81.9%) compared with the peat bog with the removed peat layer (23.8 - 11.4 %) except forest peat bog with removed peat layer (77. 1%) in 0-30 cm layer. Significant differences were established in the crop rotation field and meadow (0-30 cm) with removed peat bog soil at $P<0.05$ level of probability. Peat soil where perennial grasses were grown and fertilised by commercial fertilisers (NPK) accumulated much more humus compared to non - fertilised grassland soil. pH of all investigated treatments ranged from 5.5 to 7.2, and the lowest values of pH were measured in the forest soil with removed peat layer, and conversely – the highest values were measured in crop rotation field and meadow with removed peat layer.

Fertilised perennial grasses peat soil (80.7 – 83.0 %) and red clover and timothy mixture (73.5 - 79.7 %) with non-removed peat layer were rich in humus, the remaining differences are influenced by the agricultural management (crops, fertilisation) applied previously. Humus in arable crop rotation and meadow peat soil with removed peat layer
(0–30 cm) was a few times lower (15.4–28.4 % and 7.7–14.7 % respectively) compared to the forest soil with removed peat layer (74.6–79.3%) and peat soils with non-removed peat layer. The analysis of mobile humic substances (humic and fulvic acids), extracted with 0.1 M NaOH solution, indicates that accumulation of humic substances with depth marginally increased in all treatments of peat with non-removed peat layer. The crop rotation field and unused peat bog had lower contents of mobile humic substances compared to other treatments of peat bog with non-removed peat layer.

The results in the Figure 3 indicate that mobile humic substances showed similar regularities as accumulation of humus.

A mineral fertilisation of grasses maintained SOM content tended to increase it due to a larger amount of plant residues left since the highest plant yield was obtained in this treatment. As like as SOM the lowest nitrogen (N) content in all 0–30 cm layer was established in soil with removed peat layer in the crop rotation field and in the meadow – 0.69% and 0.46% respectively. Significant differences were determined in the peat soil of crop rotation field with non-removed peat layer and crop rotation field and meadow soil with removed peat layer at P<0.05 level of probability.

The highest nitrogen content (0–30 cm) was established in the former experimental plot of fertilized perennial grasses (3.6%) and unused peat soil (2.5%) with non-removed peat layer. The nitrogen content in soil of unfertilized perennial grasses and red clover and timothy mixture were similar, 2.87% and 2.67% respectively, with depth increasing in nitrogen red clover and timothy mixture. While remaining differences are influenced by the fertilization applied previously. N content (0–30 cm) in arable crop rotation and meadow peat soil with removed peat layer was a few times lower (0.69% and 0.46% respectively) compared to the forest soil with removed peat layer (2.11%) and peat soils with non-removed peat layer. Different use of the peat bog exerted a marked effect on other soil chemical indicators (Amalevičiūtė, 2013). The highest P content (0.17 %) of peat soil was in the crop rotation field with non-removed peat layer and in opposite the lowest P content (0.02 %) was determined in peat bog soil with the removed peat soil (Figure 4). Significant differences were identified in the fertilized perennial grasses with non-removed peat bog soil with P<0.05 level of probability.

Figure 3. Mobile humic substances in differently used Terric Histosol with non-removed and removed peat layer. Radviliiškis, 2012. a) soil with non-removed peat layer: un-used peat soil (treatment 1), earlier unfertilized perennial grasses (treatment 2), crop rotation (potatoes; winter rye; red clover) field (treatment 3); red clover (Trifolium pratense L.) and timothy (Phleum pratense L.) mixture (treatment 4); fertilized with commercial NPK fertilisers perennial grasses (treatment 5). b) soil with removed peat layer: forest (treatment 1), arable crop field rotations (treatment 2) and meadow peat soil (treatment 3). LSD (least significant difference) - significant at P<0.05 level of probability.

Figure 4. Phosphorus substances in differently used Terric Histosol with non-removed and removed peat layer. Radviliiškis, 2012. soil with non-removed peat layer: un-used peat soil (treatment 1), earlier unfertilized perennial grasses (treatment 2), crop rotation (potatoes; winter rye; red clover) field (treatment 3); red clover (Trifolium pratense L.) and timothy (Phleum pratense L.) mixture (treatment 4); fertilized with commercial NPK fertilisers perennial grasses (treatment 5). b) soil with removed peat layer: forest (treatment 1), arable crop field rotations (treatment 2) and meadow peat soil (treatment 3). LSD (least significant difference) - significant at P<0.05 level of probability.
Phosphorus promoted the mineralization of crop rotation fields. In this treatment was found the lowest content of mobile humic acids and this means lower humification. This regularities the data of other researchers, who found a negative correlation between P and the humic acids in peat bogs (Satrio et al., 2009).

Higher carbon and nitrogen contents in peat soil increase the productivity of swards cultivated there. Herbage dry matter yields produced in grasslands established on the peat bog soil with non-removed peat layer significantly higher than those produced on the peat bog soil with removed peat layer (Bilevičius, Puodžiukynas, 1996). The highest carbon to nitrogen ratio (C:N) - 21.4 was determined in the soil of forest with removed peat layer (Table 1), and the lowest C:N -13.1 was found in the soil of former fertilized perennial grasses in the peat soil with non-removed peat layer (Table 2), and the lowest (251) was determined in the soil of red clover and timothy mixture peat bog soil compared to unused peat bog at P<0.05 level of probability. The highest differences of C:N compared with the check of unused peat bog soil treatment were determined in of red clover and timothy mixture soil by 34% (in relative values) and by 29% of crop rotation field with non-removed peat layer.

Table 1. Effect of soil used on C:N ratio in different layers with non-removed peat layer, Radviliškis, 2012

<table>
<thead>
<tr>
<th>No.</th>
<th>Treatment</th>
<th>0-10 cm</th>
<th>10-20 cm</th>
<th>20-30 cm</th>
<th>Average (0-30 cm) / % from check</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Unused peat bog</td>
<td>12.3</td>
<td>13.2</td>
<td>14.1</td>
<td>13.2/100</td>
</tr>
<tr>
<td>2.</td>
<td>Unfertilized perennial grasses</td>
<td>14.3</td>
<td>13.8</td>
<td>16.4</td>
<td>14.8/112</td>
</tr>
<tr>
<td>3.</td>
<td>Crop rotation field</td>
<td>16.1</td>
<td>19.7*</td>
<td>15.3</td>
<td>17.0*/129</td>
</tr>
<tr>
<td>4.</td>
<td>Red clover and timothy mixture</td>
<td>21.0*</td>
<td>16.5</td>
<td>15.7</td>
<td>17.7*/134</td>
</tr>
<tr>
<td>5.</td>
<td>Fertilized perennial grasses</td>
<td>12.9</td>
<td>12.8</td>
<td>13.6</td>
<td>13.1/99</td>
</tr>
</tbody>
</table>

* - significant at P<0.05 level of probability

Table 2. Effect of soil used on C:N ratio in different layers with removed peat layer, Radviliškis, 2012

<table>
<thead>
<tr>
<th>No.</th>
<th>Treatment</th>
<th>0-10 cm</th>
<th>10-20 cm</th>
<th>20-30 cm</th>
<th>Average (0-30 cm) / % from check</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Forest</td>
<td>19.2</td>
<td>23.4</td>
<td>21.5</td>
<td>21.4/100</td>
</tr>
<tr>
<td>2.</td>
<td>Crop rotation field</td>
<td>22.0</td>
<td>17.5</td>
<td>19.4</td>
<td>19.7/91.9</td>
</tr>
<tr>
<td>3.</td>
<td>Meadow</td>
<td>11.1</td>
<td>23.4</td>
<td>11.4</td>
<td>15.3*/71.6</td>
</tr>
</tbody>
</table>

* - significant at P<0.05 level of probability

The C:P ratio (in average of 0-30 cm layer) was significantly higher compared to C:N ratio, and was the highest (2016) in the forest of peat bog with removed peat layer (Table 3). In opposite, the lowest (251) was determined in the crop rotation of peat bog with non-removed peat layer. Significant differences were identified in the crop rotation field and meadow peat bog soil with removed peat soil at P<0.05 level of probability. The highest differences (129%) from the check were measured in the soil with non-removed peat layer of fertilized by commercial mineral fertilisers perennial grasses.

Table 3. C:P ratio of non-removed peat bog soil, Radviliškis, 2012

<table>
<thead>
<tr>
<th>No.</th>
<th>Treatment</th>
<th>0-10 cm</th>
<th>10-20 cm</th>
<th>20-30 cm</th>
<th>Average (0-30 cm) / % from check</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Unused peat bog</td>
<td>236</td>
<td>278</td>
<td>284</td>
<td>266/100</td>
</tr>
<tr>
<td>2.</td>
<td>Unfertilized perennial grasses</td>
<td>237</td>
<td>252</td>
<td>272</td>
<td>254/96</td>
</tr>
<tr>
<td>3.</td>
<td>Crop rotation field</td>
<td>238</td>
<td>243</td>
<td>270</td>
<td>251/94</td>
</tr>
<tr>
<td>4.</td>
<td>Red clover and timothy mixture</td>
<td>292</td>
<td>298</td>
<td>350</td>
<td>313*/118</td>
</tr>
<tr>
<td>5.</td>
<td>Fertilized perennial grasses</td>
<td>325</td>
<td>342</td>
<td>363*</td>
<td>343*/129</td>
</tr>
</tbody>
</table>

Table 4. C:P ratio of removed peat bog soil, Radviliškis, 2012

<table>
<thead>
<tr>
<th>No.</th>
<th>Treatment</th>
<th>0-10 cm</th>
<th>10-20 cm</th>
<th>20-30 cm</th>
<th>Average (0-30 cm) / % from check</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Forest</td>
<td>1568</td>
<td>2162</td>
<td>2318</td>
<td>2016/100</td>
</tr>
<tr>
<td>2.</td>
<td>Crop rotation field</td>
<td>884*</td>
<td>725*</td>
<td>1052</td>
<td>887*/44</td>
</tr>
<tr>
<td>3.</td>
<td>Meadow</td>
<td>194*</td>
<td>1788</td>
<td>687*</td>
<td>890*/44</td>
</tr>
</tbody>
</table>

* - significant at P<0.05 level of probability

Mineralization and immobilization of phosphorus occur simultaneously in the soil. The C:P ratio determines whether there is net mineralization or net immobilization. When the C:P ratio is less than 200:1, net mineralization prevails. Net mineralization indicates that there is enough phosphorus in the soil to sustain both plants and microorganisms. When the C:P ratio is between 200:1 and 300:1, immobilization and mineralization rates are fairly equal. When the C:P ratio is greater than 300:1, net immobilization occurs (Satrio et al, 2009). During immobilization there is not enough P to sustain both plants and microorganisms; and so, microorganisms scavenge the soil for P.
Conclusions

Soil use and management affected chemical properties of peat bog. Variations in chemical compositions were observed there. The differently used peat soil has unequal content of SOM: peat bog soil with non-removed peat layer had higher amount of SOM compared to peat bog soil with removed peat layer. The soil with non-removed peat bog layer of fertilized perennial grasses and forest peat bog soil with removed peat layer had more nitrogen content compared to the other treatments. Remaining differences in nitrogen content are influenced by the fertilization applied previously. The highest P content (0.17 %) of peat soil was in the crop rotation field with non-removed peat layer and in opposite the lowest P content (0.02 %) was determined in peat bog soil with the removed peat layer. The higher content of P influenced mineralization in the soil. In the crop rotation field with non-removed peat layer one from factors, influencing mineralization, was determined the highest content of P stimulating mineralization. There was determined the lowest content of humic substances. The highest C:N ratio (21.4) was determined in the forest soil with removed peat layer, and in opposite the lowest C:N ratio (13.1) in the soil of fertilized perennial grasses with no-removed peat layer. The C:P ratio (in average of 0-30 cm layer) was significantly higher compared to C:N ratio and was the highest (2016) in the peat bog of forest soil with removed peat layer. Renaturalisation is still observed after termination the usage of the peat soil for agricultural tasks in the soil with no-removed peat layer. 12 years after termination of field experiment the differences in soil chemical composition still remained between treatments of differently used peat soil.

Acknowledgement. We acknowledge the financial assistance provided by the Project VP1-3.1-ŠMM-01-V-03-001 NKPDOKT.

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The Influence of Abiotic and Biotic Factors on the Condition of Birch Species in Lithuania

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Abstract

During recent decades the birch stands, occupying more than one fifth of all forest stands in Lithuania, gaining higher economic value and more significance in the Baltic region. The aim of this study was to analyse the condition of two native birch species in Lithuania – silver (Betula pendula Roth.) and downy birch (B. pubescens Ehrh.) – in relation to the main environmental factors.

The results showed that the mean defoliation of the birch species ranged between 16.2 and 23.0% in 1989–2011-year period. There were no clear dynamics of the number of birch trees damaged by abiotic and biotic factors. The significant peaks were registered in 1993–1995 and 2003–2004 because of storms or pest outbreaks. By 20% higher mean defoliation was recorded for the trees that were damaged by biotic than abiotic factors. The number of trees damaged by wind varied a lot: from no wind damages (in 1992–1993; 2005–2007) up to 87–100% (in 2001–2004) from all abiotic factors. The number of birch trees damaged by insects showed significantly decrease starting from 1991.

Introduction

Forest health being one of the basic criterions for a sustainable forest management has been monitored for more than twenty years under the International Co-operative Program on Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests) in Europe. European forests have gained attention of scientists and politicians in the eighth decade of the last century, when a massive forest degradation and death occurred in the Western and Central Europe (Germany, Czech Republic, Austria, Poland) in the territory called the Black Triangle. Then, air pollution was indicated as one of the reasons causing the significant tree canopy depression, dryness of branches and tops, furthermore, the changes of crown shape and tree death (Shutt, Cowling, 1985).

Lithuania has an unfavourable geographical position because the transboundary pollution with the prevailing south-west winds moves from the most polluted western and central European regions (Juknys et al., 2002). Other not less important factors affecting forest ecosystems are anthropogenic (direct human damage during harvesting operations, etc.), abiotic (wind, snow, etc.) and biotic conditions (insects, animals, plant diseases, etc.), also the change of climate conditions (higher air temperatures during the growing season, more frequent summer droughts) (Bredemeier et al., 1998; Ozolinčius, Stakėnas, 2001; Hu et al., 2008; Hützl et al., 2009; Ozolinčius ir kt., 2009; Johnson, Jacob, 2010; Fabiánek et al., 2012; Stakėnas et al., 2012).

Birch stands for many decades has been insufficiently valued in Lithuania because of economic reasons. In the recent years, the demand and price of birch wood increased, furthermore, this tree species is becoming one of the most perspective tree species. Similarly, birches in other Baltic and Scandinavian countries are highly valued for various reasons (for example, afforestation of abandoned farmlands) (Elfving, 1986; Ekstrom, 1987; Gustavsson, 1991; Karlsson, 1994). Increasing popularity of birch species in our country encourages us to study the condition of the birches in more detail. Also, up to now there are not many studies based on individual tree species, in our case – dominated birch species.

In Lithuania only two species – silver birch (Betula pendula Roth.) and downy birch (B. pubescens Ehrh.) – form the stands. The birch stands comprise over 22.3% of all stands (ME/SFS, 2012). Silver birch is more common in Lithuanian forests; also natural hybrids of these two species are very common in the forests. Furthermore, the conditions of silver and downy birches in individual years are quite similar (Ozolinčius et al., 1999). In this study we merged the data of these two species.

Crown condition as an active part of the tree is greatly affected by such factors as tree age, genetic factors, shading, also not less important abiotic or biotic damage, especially snow, wind, ice, game, insect defoliators, needle casts and decay fungi. Generally, environmental stresses, most often droughts, low temperatures, wind storms, tend to be especially important for tree condition or even cause the death of tree. The most biotic effects occur when insects, ungulates or humans damage the tree tissues essential for growth, may kill trees or predispose them to mechanical failure. Humans also are attributed to the major biotic cause of tree death, acting both directly and indirectly in influencing almost all other agents (Franklin et al., 1987).

In the present study we analyse the condition of two native birch species in Lithuania – silver birch (Betula pendula Roth.) and downy birch (B. pubescens Ehrh.) – in relation to the main environmental factors (abiotic and biotic). More specifically, the objectives of our study were: to compare the condition of the birch trees belonged to the different social status classes after Kraft (1 – dominant, 2 – codominant, 3 – subdominant); and to define the influence of the most frequent damages (wind damages which comprise over 70% from all abiotic damages, and insects – more than half from all biotic damages) to the birch species.
Material and methods

In Lithuania, ICP Forest Level I monitoring is carried out since 1987. The network of the Level I forest monitoring was integrated into the National forest inventory plots network in 2008. The National Forest Service has been coordinating Forest monitoring and carrying out the works of the Level I since 2003.

The condition of birch stands was analysed using the data of Level I forest health monitoring during the 1989-2011-year period. For the assessment, over one thousand of birch trees were assessed in the permanent observation plots in Lithuania (Stakėnas et al., 2013).

When analysing the tree condition, mean tree crown defoliation and number of damaged or healthy trees are usually used. According to the ICP Forest Manual (http://www.icp-forests.org/Manual.htm, 2010), the tree crown defoliation is defined as needle/leaf loss in the assessable crown as compared to a reference tree. Also, the defoliation is observed regardless of the cause of foliage loss, including various damages (insects and etc.). Defoliation was assessed in 5% steps, the defoliation classes were distinguished 0 – defoliation 0–10%; 1 – 10–25%; 2 – 25–60%; 3 – 60–95% and 4-100% (dead trees).

The defoliation of trees without symptoms of damages comprise about 20% (Ozolinčius and Stakėnas, 1996) and damaged trees have significantly higher crown defoliation than undamaged trees (Ugarković et al., 2012)

Generally, the causal factors of tree damages are grouped into some categories: game and grazing, insects, fungi, abiotic agents, direct action of men, fire, atmospheric pollutants and other factors (http://www.icp-forests.org/Manual.htm, 2010). Still, in our study we divided these factors into two groups: abiotic and biotic, then revealed the most dominant damages for birches in Lithuania.

For the purpose to compare the influence of the social status of tree, we divided three social status classes after Kraft, where to the 1st class belonged the dominant trees with upper crown standing above the general level of the canopy, to the 2nd – codominant trees with crowns forming the general level of the canopy, and to the 3rd - subdominant trees extending into the canopy and receiving some light from above, but shorter than 1st or 2nd class. The suppressed (4th class) and dying (5th) trees were ignored in this study because they are not recommended assessment in forest monitoring (http://www.icp-forests.org/Manual.htm, 2010).

The basic statistical data analysis (a mean and a standard error) and mean comparison analysis were performed using the Statistica 7.0 and Excel.

Results

Mean defoliation of birches in Lithuania in 1989–2011-year period ranged between 16.2–23.0% and showed very slight trend of degradation (Fig. 1). As a discussion point, the mean crown defoliation of eight dominant tree species in Lithuania during the same period varied in a range of 18.8–24.2% (Stakenas et al., 2013), thus the defoliation of the birch stands ranged between these limits.

![Figure 1. Mean defoliation (%) of all birch trees, damaged and healthy trees in 1989-2011.](image-url)

When analysed the differences of crown defoliation of birch trees of the different social status classes (after Kraft), the lowest defoliation was typical for dominant and codominant trees (Fig. 2). In the recent years, their crown defoliation was by 1.3–1.5 times lower if to compare with the subdominant trees (3rd Kraft class). Similar results were obtained in Scots pine stands in Lithuania (Ozolinčius and Stakėnas, 1996).
Figure 2. The crown defoliation (%) of the birches belonged to the different social status classes after Kraft: I – dominant, II – codominant, III – subdominant.

No clear dynamics during the studied period was found for the number of damaged trees both by abiotic and biotic factors (Fig. 3). Some peaks were registered for biotic factors, for example, 1991–1993, 2003–2004 and starting from 2009, one increase period was observed for abiotic factors, i.e. 1993–1995 (Fig. 3).

Figure 3. Number of birch trees damaged by abiotic (A) and biotic (B) factors and the crown defoliation (%) of trees damaged by abiotic and biotic factors, respectively.

The increased number of damaged birch trees was caused by various reasons. For example, in 1993–1995-year period, the increase of damaged trees up to 20.4–25.2% could occur as a result of storms in 1993 winter which, subsequently, increased the number of insect damages. The second increase period (the increase up to 21–22.6%) was obtained in 2003–2004 and this could be caused by insect outbreak.
Damaged birch trees composed about 14% of all damaged trees in Lithuania during the 1991-2010-year period. When compared the cases of birch abiotic and biotic stresses, we found that biotic damages comprised about 85%, i.e. they were mainly dominated. The comparison of abiotic and biotic factors, excluding the value of the number of damaged trees, showed that much higher mean defoliation during the 1991–2011-year period was recorded for the trees that were damaged by biotic than abiotic factors. This difference comprised over 20%.

For the analyses of the influence of the most frequent damages, as examples of both, abiotic and biotic, factor groups were analysed, i.e. two dominated environmental stresses were analysed: wind damages (70% of abiotic and about 10% of total damages) and insects (62% of biotic, 49% of total). The number of birch trees damaged by wind varied a lot in the whole 1991–2011-year period (Fig. 4A). There were some shorter periods (1992–1993, 2005–2007) when no wind damages were recorded. The highest number of wind damaged trees (87–100% from total number of trees damaged by abiotic factors) was found in 2001–2004. The number of birch trees damaged by insects showed a significant decrease trend ($R^2=0.7$) starting from 1991 (Fig. 4B). Despite this fact, we recorded a significant peak in 2004–2005 when the number of insect damages increased up to 70–95% from total amount of biotic stresses. Nevertheless, the condition of damaged birches varied within a relatively narrow range: the mean defoliation of damaged trees amounted between 20–30% during the whole period (Fig. 4B).

Other data analyses indicated that the highest number of damaged birch trees (29.4%) was recorded in 2012 (Stakėnas et al., 2013). Such deterioration of birch condition in the recent years occurred because of the damages caused by leaves violating insect Pandemis sp. The damages of the individual trees were first registered in 2011, but its spread covered over 100 ha of birch stands already in 2012 (VMT/MSAS, 2013). It could be predicted that the natural area boundaries of this insect in Lithuania are expanding due to the change of climate conditions.
Conclusions

The analyses of the condition of two native birch species (Betula pendula Roth. and B. pubescens Ehrh.) in Lithuania showed that mean defoliation in 1989–2011-year period ranged between 16.2–23.0% and showed very slight trend of degradation. Up to 1.3–1.5 times lower defoliation was typical for dominant and codominant birch trees (1st and 2nd Kraft classes) if to compare with the subdominant trees (3rd Kraft class).

There were no clear dynamics of the number of birch trees damaged by abiotic and biotic factors during the 1991-2011-year period. Some significant peaks were registered, for example, in 1993–1995 and 2003–2004 because of strong environmental stresses (storms or pest outbreaks).

By 20% higher mean defoliation during the 1991–2011-year period was recorded for the trees that were damaged by biotic than abiotic factors. Wind damages (comprised over 70% of abiotic and about 10% of total damages) in 1991–2011-year period varied a lot: from no wind damages in 1992–1993, 2005–2007 up to 87–100% (from all abiotic factors) in 2001–2004. The number of birch trees damaged by insects (62% from biotic, 49% from total damages) significantly decreased from 1991 but no clear changes in mean defoliation were recorded.

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**Heracleum sosnowskyi** (*Apiaceae*) Spread and Phytotoxicity

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**Abstract**

In the native range endemic species *Heracleum sosnowskyi* occurs in Caucasus region. *Heracleum sosnowskyi* is a dangerous invader successfully spread along roads, riverbanks and has naturalized in Lithuanian habitats and plant communities. It outcompetes native species, thus changing ecosystems diversity, pushing autochthones species from native habitats, decreasing biodiversity and transforming landscape. This paper aims to evaluate *H. sosnowskyi* spread and establishment in habitat scale in Lithuania. Data on abundance, spatial distribution and contribution of *H. sosnowskyi* to plant biodiversity were collected from natural and anthropogenic habitats. Another objective was to evaluate the spread speed in infected landscape. Local assessments of the abundances of *H. sosnowskyi* by estimating variables of spatial penetrating and establishment in native plant communities at an individual block scale were carried out. Four population types with different density and coverage of species individuals were found. Species abundance was structured according to distance from highway and significantly correlated (r=0.7) with native plant community type. *H. sosnowskyi* find opportunities for colonization and reproduction resulting in decrease of natural diversity.

**Keywords:** ecology, invasion level, *Heracleum sosnowskyi*, habitat, Lithuania

**Introduction**

Increasing human activity resulted in a concomitant increase of alien plant spread into new habitats (Gulezian, Nyberg 2010, Miller et al. 2010). Consequently, expansion of hemerophilous species changed native floras composition and represents one of the greatest threats to biodiversity worldwide and is considered a major driver of global change (Foxcroft et al. 2011, Mack et al. 2000, Mooney and Hobbs 2000). Plant species ranked as invasive have a diversity of life cycles, habitats etc. (Kački, Michalska-Hejduk 2010). Invasive alien (non-native) species (IAS) overcome a different category of barriers, produce reproductive offsprings, sustain populations and thus have the potential to spread over a considerable area (Kowarik 2011, Moravcová et al. 2005, Pysek et al. 2007).

Several species of the genus *Heracleum* (*Apiaceae*) were introduced into Europe from south-west Asia in the 19th century and are now widespread in many countries (Kabuce and Priede 2010). *Heracleum sosnowskyi* is an invasive tall forb listed among 6 dangerous invader species successfully spread across roadsides, natural riparian zones and forest edge habitats in Lithuania (List..., 2009). *H. sosnowskyi* originates in the central and eastern Caucasus and western, central, eastern and southwestern Transcaucasia and in northeastern Turkey where it occurs in the upper forest belt of the southern slopes, mainly in meadows, clearings and forest edges (Jahodová et al. 2007, Nielsen et al. 2005). When expanding in new territories species establishes in fertile soils and completely changes habitats, making huge damage on native flora and landscape. Since plant competition is mainly for access to light therefore plant that grows higher biomass (add to the leaf area index), also creates negative feedback in the form of more self-shading and shading of its neighbors. Considering that, only shade–tolerant species persist in the community (Finnoff and Tschorhart 2009). It establishes in following habitats: pastures, river banks, roadsides and rail networks, wastelands.

This species was originally described by Mandenova in 1944 (Lapiņš et al. 2002, Oboļeviča 2001). It was promoted as a crop for northwest Russia, where it was first introduced deliberately in 1947. From the 1940s onwards, it was introduced as a potential forage crop to Latvia, Estonia, Lithuania, Belarus, Ukraine and the former German Democratic Republic (Nielsen et al. 2005). Initially *H. sosnowskyi* was introduced as fodder plant in the sixth decade of the 20th century at Research Station of Lithuanian University of Agriculture (Krikščiakas, 1970 unpubl.) and as honey plant by personal initiatives in other places of Lithuania. *H. sosnowskyi* has two major impacts: 1) it suppresses growth of native plants and fauna associated with them; 2) the plant is bioactive, since allergic furanocumarine is accumulated in all parts (FIRUZI et al. 2010, LANGLEY and CRIDDLE 2006, LANGNER et al. 2010). Direct skin contact with the plant induces extreme photosensitivity, which in turn can lead to severe, slow to heal burns and scarring. Costs are incurred therefore both for medical treatment and in implementing to keep the plant under control (EC 2001).

The objective of this study was to assess the invasion and impacts of *H. sosnowskyi* on native habitats and to record the distribution and abundance of the species in the most heavily invaded landscapes with regard to different habitat types.

**Materials and methods**

A plant data set (6 km × 10 km area) was pre-selected for near intensive traffic highway *Via Baltica*. Relevés (200.0 m²) in 5 replications were set out along transects in each study site (abandoned grasslands, open riverbanks, open roadsides, wastelands, forest edge, housing areas) during 2010-2011. The initial test data were obtained during summer (June-July) at species flowering stage. The registered plant species were listed by following the commonly used taxonomical and nomenclature interpretation (Jankeviciene, 1998). The following criteria of modified Braun-Blanquet scale were used as the basis for plant relevance: species diversity/abundance in six habitats. Invasion percentage of *H. sosnowskyi* was defined as the ratio between the area of species stands and the total area of the respective habitat type (Fig. 1) within the study areas.

The phytotoxicity of *H. sosnowskyi* aqueous extracts were examined at different plant growth stages: rosette (39 BBCH; end of May), flowering (65 BBCH; end of June) and milky stage (76 BBCH; end July). The aqueous extracts
were diluted to 0.02, 0.05, 0.1 and 0.2% (w/v) concentrations and used for germination assays. Oil rapeseed (Brassica napus L.) cv. Kasimir (NPZ / Saaten-Uninio, Germany) and perennial ryegrass (Lolium perenne L.) cv. Sodrė were chosen as acceptor plants. One hundred seeds were placed on filter paper in each Petri dish (6-cm dia). Five ml aqueous plant extract (0, 0.02, 0.05, 0.1, and 0.2 % w/v) concentrations was added per Petri dish as per treatment.

The significance of species response to *H. sosnowskyi* invasion was verified using one-way analysis of variance (ANOVA). Standard error (SE) of the presentation of each species was recorded in investigated sites at statistical significance p<0.05.

**Results**

*Heracleum sosnowskyi* was found established in differently anthropogenized habitats. Mature *Heracleum sosnowskyi* successfully spread and develop substantial competition facilities due to giant body and high seed productivity. Mature plant has pinnately divided leaves of 1 m in size, a hollow flowering stem with height up to 3 m (4.5 m); it regrows from the large fleshy tap root in spring; stem diameter in basal part is 12-15 cm. Insect-pollinated, hermaphrodite flowers are arranged in compound umbels, with the terminal umbel being the largest one, up to 51-74 cm across its base (Table 1). Some 6-7 lateral umbels are located below terminal umbel. Umbels mature in sequence. The lateral inflorescence diameter ranged between 25 and 32 cm. Total plant generative production ranged between 7722 and 8082 mericarps with 15444-16164 seeds in all assessed habitats.

The main spread corridor of *Heracleum sosnowskyi* was located on the roadside of highway and river bank (Table 2). Initial populations of *Heracleum sosnowskyi* generally occurred near roads and were composed of 1-2 individuals. The species established the largest populations in wasteland, rangeland, along roadsides. It also penetrated in semi natural and natural habitats (slopes, meadows, river banks, forest edges) where thus form large populations during a longer period of 6-10 yrs in absence of interferences. Uncontrolled species formed large pure colonies composed from few to several dozen individuals and having high cover percent of 60-80% (100%). Along the roadside of Via Baltica (central Lithuania), *Heracleum sosnowskyi* had spread over 600 m during 2000-2010, i. e. with average linear speed of 60 m per year.

<table>
<thead>
<tr>
<th>Habitat type</th>
<th>Terminal umbel</th>
<th>Lateral umbel</th>
<th>Fruit amount, un.</th>
<th>Fruit amount, un.</th>
<th>Seed per plant</th>
<th>Seed per plant</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Diameter, m</td>
<td>Umbellet, un.</td>
<td>Diameter, m</td>
<td>Number per plant</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Abandoned grasslands</td>
<td>0.51</td>
<td>86</td>
<td>0.25</td>
<td>6</td>
<td>4488</td>
<td>7722 15444</td>
</tr>
<tr>
<td>Open riverbanks</td>
<td>0.84</td>
<td>72</td>
<td>0.30</td>
<td>7</td>
<td>4858</td>
<td>8082 16164</td>
</tr>
<tr>
<td>Open roadsides</td>
<td>0.51</td>
<td>86</td>
<td>0.32</td>
<td>8</td>
<td>4944</td>
<td>8070 16140</td>
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<tr>
<td>Wastelands</td>
<td>0.62</td>
<td>89</td>
<td>0.32</td>
<td>6</td>
<td>4798</td>
<td>8032 15452</td>
</tr>
<tr>
<td>Forest edge</td>
<td>0.58</td>
<td>87</td>
<td>0.31</td>
<td>7</td>
<td>4490</td>
<td>7726 16064</td>
</tr>
<tr>
<td>Housing areas</td>
<td>0.53</td>
<td>85</td>
<td>0.31</td>
<td>7</td>
<td>4860</td>
<td>7996 15992</td>
</tr>
</tbody>
</table>

**Table 2. Population types of *H. sosnowskyi***

Different species were adjusted across the invaded habitats (Table 3). Comparison of species lists with historical data documenting pre- and post-invasion by *Heracleum sosnowskyi* indicated that herbaceous species in grass-communities were less resistant than those of tree-communities (forest edge).

Additionally, a number of native species exhibited reduced cover abundance resulted by *Heracleum sosnowskyi* invasion in different habitats (Fig. 1). The highest reduction (43%) of relative cover was observed in invaded grasslands, while it composed 75% in forest edges. Consequently, the highest invasion percentage (12.3%) was found in open roadsides and was followed by abandoned grasslands (6.70%), wasteland areas (2.40%), open riverbanks (1.20%).
Table 3. Frequency (%) of adjusted species in different communities with *H. sosnowskyi* (mean±SE, p<0.5)

<table>
<thead>
<tr>
<th>Plant community</th>
<th>Constant species</th>
<th>Frequency, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Herbaceous</td>
<td>Anthriscus sylvestris</td>
<td>51.9±0.11</td>
</tr>
<tr>
<td></td>
<td>Artemisia vulgaris</td>
<td>80.9±0.13</td>
</tr>
<tr>
<td></td>
<td>Cirsium arvense</td>
<td>56.9±0.10</td>
</tr>
<tr>
<td></td>
<td>Dactylis glomerata</td>
<td>76.2±0.20</td>
</tr>
<tr>
<td></td>
<td>Festuca pratensis</td>
<td>77.1±0.18</td>
</tr>
<tr>
<td></td>
<td>Euryhynchium angustirete</td>
<td>20.13±0.13</td>
</tr>
<tr>
<td>Bush</td>
<td>Anthriscus sylvestris</td>
<td>66.5±0.21</td>
</tr>
<tr>
<td></td>
<td>Artemisia vulgaris</td>
<td>55.7±0.14</td>
</tr>
<tr>
<td></td>
<td>Cirsium arvense</td>
<td>55.7±0.11</td>
</tr>
<tr>
<td></td>
<td>Dactylis glomerata</td>
<td>44.5±0.21</td>
</tr>
<tr>
<td></td>
<td>Festuca pratensis</td>
<td>44.7±0.12</td>
</tr>
<tr>
<td></td>
<td>Euryhynchium angustirete</td>
<td>88.6±0.15</td>
</tr>
<tr>
<td></td>
<td>Urtica dioica</td>
<td>25.3±0.10</td>
</tr>
<tr>
<td></td>
<td>Salix caprea</td>
<td>6.70%</td>
</tr>
<tr>
<td>Bush</td>
<td>Anthriscus sylvestris</td>
<td>66.5±0.21</td>
</tr>
<tr>
<td></td>
<td>Artemisia vulgaris</td>
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<td></td>
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<tr>
<td></td>
<td>Dactylis glomerata</td>
<td>44.5±0.21</td>
</tr>
<tr>
<td></td>
<td>Festuca pratensis</td>
<td>44.7±0.12</td>
</tr>
<tr>
<td></td>
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<td>88.6±0.15</td>
</tr>
<tr>
<td></td>
<td>Urtica dioica</td>
<td>25.3±0.10</td>
</tr>
<tr>
<td></td>
<td>Salix caprea</td>
<td>6.70%</td>
</tr>
</tbody>
</table>

Figure 4. Acceptor species germination response to phytotoxicity of *H. sosnowskyi* extracts

In the present study the obtained data indicated that the phytotoxic impact of *H. sosnowskyi* aqueous extracts on the germination of the acceptor plant seeds significantly relied on plant age, different plant parts, growth stage and extract concentration (Fig. 4). 1-year old *H. sosnowskyi* at rosette stage exhibited strong inhibitory effect on both of acceptors (rapeseed and p. ryegrass) seed germination. Therefore, the positive significant correlation (r=0.89, p<0.001) was estimated between the amount of fresh material added to the water extract and the resulting inhibition effect on germination. Noteworthy response of acceptor plant was insignificantly influenced by plant, but varied significantly (p<0.05) across plant parts, namely shoot or root. Germination rate $G_{50}$ of rapeseed and p. ryegrass ranged between 0-40 % and 4-42 % in shoot; and 2-47% and 2-47 % in root exudates, respectively. Furthermore, these germination rates ranged accordingly to the gradients of the extract concentration and phenols concentration there in.
Our research suggests that allelochemical suppression maintained by *H. sosnowskyi* against the neighbouring plants does also hold in the invaded communities. Thus prospective research into and employment of *H. sosnowskyi* allelopathic effects in environment may have important implications on the plant communities’ susceptibility to invasion. Moreover, secondary metabolites (high content of phenolics etc.) deter herbivores thus providing invader species i.e., *H. sosnowskyi* with successful spread in new territories.

**Conclusion**

Highway roadsides present the main invasion corridor of *H. sosnowskyi* in Lithuania. 80% of *H. sosnowskyi* colonies were established in anthropogenized areas: wastelands, roadsides and housing areas, and only 20% of colonies penetrated in natural habitats. Significantly (r=0.7) the highest invasion percentage (12.3%) was found in open roadsides and was followed by abandoned grasslands (6.7%), wasteland areas (2.4%), open riverbanks (1.2%). Respecting intensive generative reproduction by seeds (average 15444-16064 seeds per plant) *H. sosnowskyi* rapidly spread, and thus has significant negative consequences for both human enterprise and native ecological systems. Phytotoxic impact of *H. sosnowskyi* aqueous extracts inhibited germination of the acceptor species seeds and significantly relied on plant age, different plant parts, growth stage and extract concentration.

**References**


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The Influence of Enclosed Fallow Deer’s on Soil Chemical Properties

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Aleksandras Stulginskis University, Lithuania

Abstract

Introduction of new species could have risk for stability of ecosystems, populations and communities. Herbivores can have important direct and indirect effects on belowground properties and processes that govern ecosystem structure and productivity. A few studies about influence of fallow deer on soil chemical properties were performed. In this study, we examined the effects of fallow deer kept in enclosures on soil chemical properties. The study was carried out in enclosures of Anyksciai, Panevezys, Kaisiadorys and Raseiniai State Forest Enterprises. Spruce, mixed spruce and birch stands dominated in enclosures. The significant effect of fallow deer on soil nitrogen has the potential to reduce ecosystem productivity.

We collected soil samples (0-20 cm soil layer) in enclosures and in near-by stands outside enclosures as control. We measured pH, total nitrogen, mineral N-NH4+, N-NO3- and mobile phosphorus. The aim of the study was to examine influence on soil chemical properties.

Keywords: the fallow deer, soil, total nitrogen, acclimatization, enclosures.

Introduction

Fallow deer (*Cevus dama* LINNE, 1758) were first animal species introduced to Lithuania. Most likely fallow deer were introduced to Lithuania in XVII century and breed in parks as decoration, and in hunting forests as valuable game species. According to 1940 data records of hunting fauna fallow deer existed in Joniskis, Kursenai, and Siauliai State Forest Enterprises. During the post-war period most fallow deer were in Akmene and Siauliai districts, where number of fallow deer ranged from 21 (in 1948) to 350 (in 1969). Still scientists supposed, that during the post-war period that there were no fallow deer, or they extincted soon, and wrongly, young red deer where recognized as fallow deer (Baleisis et al., 2003). Following acclimatization of fallow deer started in 1976-1977, when 90 fallow deer where moved to enclosures, located in Silute and Marijampole districts (Petelis, 1998, 2004). Presently in Lithuania only acclimatization of fallow deer is processing.

Methods and materials

The study was carried out in enclosures of Anyksciai, Panevezys, Kaisiadorys and Raseiniai State Forest Enterprises. The aim of the study was to examine influence of enclosed fellow-deer on forest soil chemical properties.

Figure 1. Areas of investigation
Spruce, mixed spruce and birch stands dominated in enclosures. We collected soil samples (0-5, 5-10, 10-20 cm soil layer) in enclosures and in nearby stands outside enclosures as control. Soil samples from the 50 spot-probe samples were collected randomly from each area in three replicates in July 2011-2012 (ISO 10381-2:2005). After that soil samples were air-dried at room temperature, crushed and sieved at 2 mm mesh (ISO 11464:1994). Total nitrogen (N) amounts were determined by the Kjeldahl method (ISO 11261:1995). Nitrate nitrogen (NO3-N) amounts were determined in the aqueous soil extracts (v/v 1:5) by the spectrophotometric method using sulfosalicylic acid (LST EN ISO 7890-3:1998 E). Ammonium nitrogen (NH4-N) amounts were determined in the soil aqueous extracts (v/v 1:5) by spectrophotometric method (LAND 38-2000). All chemical analyses were carried out in three analytical replicates.

Results

The aim of our study was to investigate the impact of enclosed fallow deer on forest vegetation and soil chemical properties. We pose the hypothesis that high density of animals in the enclosure decreases the amount of undergrowth and soil chemical properties.

Introduction of new species could have risk for stability of ecosystems, populations and communities. Herbivores can have important direct and indirect effects on belowground properties and processes that govern ecosystem structure and productivity. We measured pH, total nitrogen, mineral N-NH4+, N-NO3- and mobile P2O5.

Figure 2. Mobile P2O5 (± standard deviation)

Mobile phosphorus did not differ between soil in enclosure and outside it. The significant effect of grazing on soil mobile phosphorus was in mixed spruce areas.

Plant available nitrogen content from 1 to 10 percent of the total nitrogen content. The mineral nitrogen was 1.5-4 percent of Nb.

Figure 3. Total nitrogen (%) in different zones (± standard deviation)

The significant effect of grazing was higher total nitrogen in enclosure than outside it.
The effects of grazing on soil nutrient cations and phosphorus were mixed. Grazing substantially reduced the quantities of extractable calcium, magnesium and phosphorus, with average reductions of about one-third. The significant effect was in enclosure, where net nitrification was three times higher with grazing than without. It was determined that soil pH was lower (3.99) in enclosure, than outside the enclosures (4.83).

Figure 4. pH in different zones (± standard deviation)

Conclusions

The significant effect of fallow deer on soil nitrogen has the potential to reduce ecosystem productivity. Grazing had effect on total soil N across all enclosures and overall effect on total soil N across all enclosures. Herbivores have important direct and indirect effects on belowground properties and processes that govern ecosystem structure and productivity.

References


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Evaluation of Lime-Based Ditch Filters for Reduction of Phosphorus Loses from Agricultural Land

Nijolė Bastienė
Aleksandras Stulginskis University, Lithuania

Abstract

Leakage of nutrients from agricultural land is one of the main causes of eutrophication of the Baltic Sea. The international project “BalticSea 2020” carries out research and measures to reduced leakage from agriculture and seeks to bind phosphorus leaching from agricultural land in the ditch close to the source, thereby reducing the discharge of phosphorus to the sea.

The results obtained in Lithuania show that the efficiency of tested filter materials varies widely during the reporting period. Mean concentrations of total phosphorus (TP) in the outflow from all tested filter materials differed significantly from those in ditch water. The filter material Polonite was distinguished by highest reduction capacity of TP (57% on the average). Slightly less reduction (by 49%) was determined using Granulated blast furnace slag and the least (26%) using Filtralite-P. Reduction capacity of phosphate phosphorus (PO$_4^{3-}$-P) was a few percentage points lower: Polonite – 52%, Slag – 44% and Filtralite-P – 20% on the average.

Introduction

Manure has been used effectively to improve crop production and soil properties because it contains nutrients and organic matter (Eghball and Power, 1994). However the improved soil properties associated with manure application lead to negative environmental impact to receiving waters. Part of the nutrients in manure run off with rain water and leach through the soil to ditches and rivers and end up in lakes and seas. This so-called "diffuse leakage" is the largest source of algal blooms, oxygen depletion and dead zones in the Baltic Sea. Point-sources of water pollution have been reduced due to their ease of identification and treatment. As water quality problems remain, attention is directed toward reducing agricultural non-point-sources of P and N. Notwithstanding various strategies for P and N management were developed, because of differing biology, chemistry, and flow pathways of P and N in soil, these narrowly targeted strategies may lead to mixed results. In some cases, N management of manures has increased soil P and subsequent P enrichment of surface runoff, while no-till has reduced P losses but increased nitrate leaching (Heathwaite et al., 2000). Areas most vulnerable to P loss are near the stream channel. In contrast to P, larger areas contribute to nitrate leaching where freely draining soils and high manure and fertilizer N applications are made. Thus, different strategies may be appropriate for different areas of a watershed.

The impact of manure applications on phosphorus transport through the soil into subsurface drains was investigated by Georhing et al., (2001). Field and column studies indicate that high P concentrations in the tile drain effluent can be attributed to macropore transport processes. Contamination of receiving waters is most likely to occur when precipitation follows manure application closely. Cumulative TP loss was significantly higher from wet than dry plots. Vadas et al. (2007) have analysed hydrology and groundwater nutrient concentrations in a ditch-drained agroecosystem. They reported that delivery of groundwater P to shallow ditches was apparently controlled by near-ditch soil P conditions, while P delivery to deep ditches was controlled by how groundwater flowed. Arheimer and Liden (2000) found that concentrations of different phosphorus species were highly correlated to soil texture. Therefore the understanding of spatial and temporal variability phosphorus concentrations is needed in order to develop decision-making tools.

Despite mitigation measures for phosphorus already being made, leakage of phosphorus is still much too high (Djodjic and Bergström, 2005). To achieve rapid mitigation effects, measures should be done in and at ditches downstream the arable land. Protective zones and construction of wetlands are measures already in use today, but they are not efficient enough to obtain aspired result of reduced leakage of phosphorus (Abu-Zreig et al., 2003; Braskerud et al., 2005; Hoffmann et al., 2009). These measures also reduce a significant area of agricultural land and are not always welcomed by farmers.

Studies of Renman A. and Renman G. (2010) show that filters with different filter materials are effective to separate phosphorus from sewage water. They should have good potential also with water from agricultural land, even if the levels of phosphorus are lower. Findings of Leader et al. (2008) suggest that calcium-based (Ca) and an iron-based (Fe) phosphorus sorbing materials removed substantial amounts of P from agricultural surface runoff, subsurface runoff, and or wastewaters. These materials also had the potential to remove P from solution low in P. Therefore, these materials may be useful for land applying to soil, co-blending with manures and biosolids, and amending constructed wetland soils to reduce P solubility and increase P retention by these practices. These materials also contain plant nutrients and thus, may be further desirable as agricultural soil amendments. Further, they may provide additional benefits for soil quality such as increased cation exchange and water holding capacity, which in turn has benefits for agricultural crops.

Sam Ekstrand from IVL Swedish Environmental Research Institute hopes to reduce the leaching of nutrients from fields using calcium based filters (Ekstrand et al., 2010). IVL has recently estimated the potential of ditch dams and lime cassettes: •Potentially 80-100% reduction of dissolved Phosphorus (mainly Phosphates), which is the main part of the bio-available fraction; •10-30 % reduction of particulate Phosphorus; •The sediment of the dam can be removed.
and re-used; • The used filter material can potentially be spread on the fields; • Requires no additional land area; • Applicable for a large part of the arable land in the Baltic Sea States; • Simple and cheap mitigative action.

International research project “BalticSea 2020” carries out research and measures to reduce leakage from agriculture. This project seeks to bind phosphorus leaching from agricultural land in the ditch close to the source, thereby reducing the discharge of phosphorus to the sea. The objective of this project is to clarify the large-scale applicability of the technology in the Baltic Sea region, and the overall potential impact on emissions of phosphorus to the Baltic Sea. During Phase II, which began in late 2011, the technology will be evaluated and demonstrated in Poland and the Baltic States, where soils and growing conditions are different compared to the Swedish situation.

Material and Methods

The site for investigations of ditch filters in Lithuania was selected jointly by ASU and IVL. Selection was based on high phosphorus concentrations in surface water bodies. It locates at the Pasodele pig breeding farm in Panevezys district 30 km from Kedainiai (55°33′49″N; 24°2′57″E) (Fig. 1). Liquid manure (105 387 m$^3$) formed in this farm annually was applied in the surrounding fields in accordance with the fertilization rates and terms - no more than 170 kg N per ha per year. Nevertheless, the quality of surface water bodies both above and below the farm’s area does not meet good ecological status by nutrients in the water.

The three concrete wells with different phosphorus sorbing materials were installed on the slope of the ditch which drains the arable land (approximately 358 ha) around the farm therefore large amounts of phosphorus leaches to the surface waters. This ditch discharges into the Lokauša stream - second range tributary of the Nevėžis river. Nevėžis basin is characterized by high agricultural pollution and high phosphorus load (15-26 kg/ha). Before installation of filter wells in drainage water discharged to the ditch 1.2 mg l$^{-1}$ (TP) and 1.13 mg l$^{-1}$ (PO$_4$-P) were determined (Table 1). At the same time ditch water near the place provided for filter wells installation contained 0.43 mg l$^{-1}$ (TP) and 0.42 mg l$^{-1}$ (PO$_4$-P). According to water quality standards in Lithuania such quantities of phosphorus (>0.4 mg/l) indicates bad water quality.

Table 1. Phosphorus concentrations in ditch water before installation of filter wells

<table>
<thead>
<tr>
<th>Date</th>
<th>Observation points</th>
<th>TP, mg/l</th>
<th>PO$_4$-P, mg/l</th>
</tr>
</thead>
<tbody>
<tr>
<td>18 04 2012</td>
<td>1</td>
<td>1.200</td>
<td>1.130</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>0.431</td>
<td>0.423</td>
</tr>
</tbody>
</table>

Figure 1. Location of ditch filters

Soil samples were taken at three points near the ditch at the depths of 0–20, 50–60 and 90–100 cm in May 2013. It was found that moderately coarse texture – sandy loam soil moderate rich in humus (1.8-3.4 %) prevailing in the experimental site. Mean phosphorus content in the plough-layer (0–20 cm) ranges from medium to very high (120–207 mg kg$^{-1}$), in deeper layers it decreased to 44-155 mg kg$^{-1}$, while at the depth of 1.0 m it was very low and ranges from 33 to 63 mg kg$^{-1}$.

Three phosphorus sorbing materials were tested for its phosphorus removal capacity:

- **Polonite** (calcium silicate-based material used for absorption and recycling of phosphorus);
- **Filtralite-P** (fine grained filter material, with a large surface area and a high capacity for phosphorus removal developed using clays and natural additives);
- **Slag** (byproduct of steelmaking, it is largely limestone or dolomite which has absorbed phosphate from the iron ore being smelted).

The phosphorus reduction capacity conducted using water quality monitoring before and after the filter installations. Generally water sampling was done once a week. Chemical analyses were carried out in accredited Chemical analytical laboratory (Licence No. 1005542) of Aleksandas Stulginskis University. Water samples were analysed for TP and PO$_4$-P. Concentrations were determined by the spectrometric method with FIA Star 5012 system analyser according to the water quality investigation standards (LAND 58:2003).

At each sampling occasion the water level at the Thompson triangular overflow weir (measured using e+Water L sensor/logger (manufactured by Eijkelkamp)) as well as water discharge from each filter well (measured by volumetric way) was noted. Ditch discharge was calculated using the equation $Q = 0.0146 (h^{2.5}) (h – the height of accumulation)$.

**Meteorological conditions.** Meteorological data were recorded by a nearest (24 km from experimental site) meteorological station Dotnuva. The lowest average temperatures were recorded in January and March –7°C and –
4.8°C respectively, the highest ones – in June – +18.6°C (Table 2). In February mean temperature was by 3°C higher the climate standard (due to the climate changes higher temperatures were frequent in winter-spring months in Lithuania). For the positive temperature this month was the wettest: precipitation made 1.7 of monthly norm. In March the weather cooled down again and precipitation made only quarter of monthly norm.

<table>
<thead>
<tr>
<th>Month</th>
<th>Precipitation</th>
<th>Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Monthly amount</td>
<td>Deviation from the climate standard</td>
</tr>
<tr>
<td></td>
<td>% of the climate standard</td>
<td>Climate standard</td>
</tr>
<tr>
<td></td>
<td>Climate standard</td>
<td>Climate standard</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>-------</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Precipitation</td>
<td>36</td>
<td>43</td>
</tr>
<tr>
<td>% of the climate standard</td>
<td>106</td>
<td>172</td>
</tr>
<tr>
<td>Climate standard</td>
<td>34</td>
<td>25</td>
</tr>
</tbody>
</table>

In general the first six months in 2013 was slightly drier and warmer than usual: the total precipitation from January to July amounted to 228 mm and was 11% less than the climate standard (255 mm) and average air temperature was +4.3°C that is+0.5°C higher than the seasons climate standard +3.8°C. For this reason, the ditch was not frozen and all filters worked the entire season.

**Hydrological conditions.** Rapid worming in April caused intensive spring thaw on the second decade of this month. The highest ditch discharge 342,1 l/s was determined on 13 of April. There was 8 days period (from the tenth to the eighteenth day of April) with high flow when the weir and filter wells were impounded in which no monitoring was carried out (Fig. 2). Rest of the time the water level fluctuations in the ditch were inconsiderable and did not cause problems on the work of ditch filters because required water head more than 30 cm have been maintained.

![Figure 2](image-url)  
**Figure 2.** Fluctuation of water level in the ditch (solid red line – head of Thompson weir; dotted red line – minimum height of water accumulation); on the right – ditch discharges calculated using Thomson weir equation.

However, irrespective of constant water head, discharges from the filter wells decreased drastically already during the first three months (Fig. 3). It was supposed that water inlet collmatation occurs and flushing of the system under the high pressure was done on 9th of April. But soon after the water level in the ditch rose sharply, filter wells were submerged and measurements for the time stopped. After the flood abatement at sufficiently high water head the discharges from the filters increased only slightly for a short time. The possible reason was a collmatation of the drainage pipe perforation at the bottom of filter wells due to higher organic pollution in the ditch (BOD₇ =7.2 mg/l). Therefore the flushing was done again on 27th of May. After the such experiences can be concluded that standard perforation of 110 mm PVC drainage pipe is too small because algae rapidly clogs the entrance of the water to filter material. In such case periodic flushing under the high pressure is required.
Results

Phosphorus concentrations. The results of chemical analysis are presented in Fig. 4. The first peak of total phosphorus concentrations in the ditch as well as in the outflow from the ditch filters was observed in the first half of June: it reached 1.65 mg/l in the ditch and accordingly 1.13, 1.48 and 1.19 mg/l in the outflow from filters. Analysis showed that the main part (approximately 88%) of total phosphorus consisted of phosphate phosphorus. In many cases PO$_4$-P amounted more than 90% of TP. Only during the spring thaw due to the surface water inflow to the ditch the proportion of PO$_4$-P was relatively lower about 65% of TP.

Table 3 presents statistical estimation of the data obtained during the first six months of ditch filters investigations in Lithuania. The phosphorus concentrations in ditch water above the filters and in filters outflow were tested by estimation of data variation (F-Test for Variances) and t-Test for means (Table 4). Significant differences in means were determined at $p<0.05$ and $p<0.01$. 

Figure 3. Fluctuation of water discharges from the filter wells (F-1 – Polonite, F-2 – Filtralite-P, F-3 – Slag)

Figure 4. Total phosphorus (TP) and phosphate phosphorus (PO$_4$-P) concentrations in the ditch water and in the outflow from different filter materials (F-1 – Polonite, F-2 – Filtralite-P, F-3 – Slag)
Table 3. Variability of phosphorus concentrations in ditch water above the weir and in filter discharge using different filter materials (F-1 – Polonite, F-2 – Filtralite-P, F-3 – Slag)

<table>
<thead>
<tr>
<th>Parameters</th>
<th>TP mg l⁻¹</th>
<th>PO₄-P mg l⁻¹</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ditch</td>
<td>F-1</td>
</tr>
<tr>
<td>Count</td>
<td>31</td>
<td>29</td>
</tr>
<tr>
<td>Min</td>
<td>0.222</td>
<td>0.002</td>
</tr>
<tr>
<td>Max</td>
<td>1.65</td>
<td>1.13</td>
</tr>
<tr>
<td>Mean</td>
<td>0.636</td>
<td>0.272</td>
</tr>
<tr>
<td>Standard Error</td>
<td>0.06</td>
<td>0.05</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>0.313</td>
<td>0.270</td>
</tr>
<tr>
<td>Confidence Level</td>
<td>0.115</td>
<td>0.103</td>
</tr>
</tbody>
</table>

Table 4. The comparison of mean concentration of total and phosphate phosphorus (mg l⁻¹) calculated from the data obtained during January-June 2013

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Ditch</th>
<th>F-1</th>
<th>F-2</th>
<th>F-3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total phosphorus</td>
<td>0.636</td>
<td>0.272**</td>
<td>0.471*</td>
<td>0.325**</td>
</tr>
<tr>
<td>Phosphate phosphorus</td>
<td>0.558</td>
<td>0.269**</td>
<td>0.449</td>
<td>0.312**</td>
</tr>
</tbody>
</table>

n=30; * statistical differences at p<0.05; ** statistical differences at p<0.01

Ditch filters efficiency. The results show that mean concentrations of total phosphorus in the outflow from all tested filter materials differed significantly from those in ditch water. The filter material Polonite was distinguished by highest reduction capacity (57% on average). Slightly less reduction by 49% was determined using Granulated blast furnace slag and the least (26%) using Filtralite-P (Fig. 5). Reduction capacity of phosphate phosphorus was a few percentage points lower: Polonite – 52%, Slag – 44% and Filtralite-P – 20% on average.

Figure 5. TP reduction capacity (%) of different filter materials during the first six months of operation (F-1 – Polonite; F-2 – Filtralite-P; F-3 – Slag).

As can be seen from Fig. 5, the efficiency of tested filter materials varies widely during the reporting period. It reduced almost to a minimum in early February when the lowest concentrations of phosphorus in ditch water were determined (0.22-0.25 mg l⁻¹) and during the spring thaw. Extremely sensitive to changes in phosphorus concentrations in the ditch were Filtralite-P filter and Granulated blast furnace slag filter. This is confirmed by a regression analysis of the data (Table 5). TP and PO₄-P concentration in the outflow from Polonite and Filtralite-P filters have a strong linear relationship (r = 0.85-0.92) with phosphorus concentration in inflowing water, however Slag filter moderately response to inflow concentrations (r = 0.68-0.73).

Table 5. Relationship between phosphorus concentration in ditch filters outflow (Cᵢ) and ditch water (Cᵢ). (a and b – parameters of linear regression, r – correlation coefficient)

<table>
<thead>
<tr>
<th>Reg. equation</th>
<th>Cᵢ = aCᵢ + b</th>
</tr>
</thead>
<tbody>
<tr>
<td>Filters</td>
<td>F-1</td>
</tr>
<tr>
<td>Parameters</td>
<td>a</td>
</tr>
<tr>
<td>TP</td>
<td>0.739</td>
</tr>
<tr>
<td>PO₄-P</td>
<td>0.746</td>
</tr>
</tbody>
</table>
capacity. Regression analysis between phosphorus concentrations in filters outflow and filters discharge indicate that only Polonite filter have moderate linear the relationship, however, other tested filter materials show polynomial relationship (Table 6). Exceptionally strong relationship was established in the case of Slag filter ($r = 0.93$).

### Table 6. Relationship between phosphorus concentrations in ditch filters outflow ($C_F$) and filters discharge ($Q_F$) (a, b and c--parameters of polynomial regression, $r$ -- correlation coefficient)

<table>
<thead>
<tr>
<th>Parameters</th>
<th>F-1</th>
<th>F-2</th>
<th>F-3</th>
</tr>
</thead>
<tbody>
<tr>
<td>$C_F = aQ_F + b$</td>
<td>$C_F = aQ_F^2 + bQ_F + c$</td>
<td>$C_F = aQ_F^3 + bQ_F^2 + cQ_F + d$</td>
<td></td>
</tr>
<tr>
<td>a</td>
<td>0.12</td>
<td>0.11</td>
<td>0.09</td>
</tr>
<tr>
<td>b</td>
<td>0.62</td>
<td>0.63</td>
<td>0.63</td>
</tr>
<tr>
<td>r</td>
<td>0.67</td>
<td>0.69</td>
<td>0.72</td>
</tr>
</tbody>
</table>

So, must be concluded that sudden decrease of filters reduction capacity at the end of June cannot be completely explained neither by reduction of filter discharges nor by phosphorus concentrations in ditch water. It is clear that the flushing of filter system should be done once again and follow-up monitoring should be carried out.

### Conclusions

The results obtained in Lithuania show that mean concentrations of total phosphorus in the outflow from all tested filter materials differed significantly ($r$-test, $p<0.005$ and $p<0.01$) from those in ditch water. The filter material Polonite was distinguished by highest reduction capacity (57% on average) of total phosphorus. Slightly less reduction by 49% was determined using Granulated blast furnace slag and the least (26%) using Filtralite-P. Reduction capacity of phosphate phosphorus was a few percentage points lower: Polonite – 52%, Slag – 44% and Filtralite-P – 20%.

The efficiency of tested filter materials varies widely during the reporting period. TP and PO$_4$-P concentration in the outflow from Polonite and Filtralite-P filters have a strong linear relationship ($r = 0.85-0.92$) with phosphorus concentration in inflowing water, however Slag filter moderately response to inflow concentrations ($r = 0.68-0.73$).

Regression analysis between phosphorus concentrations in filters outflow and filters discharge indicate that only Polonite filter have moderate linear relationship, however, other tested filter materials show polynomial relationship. Exceptionally strong relationship was established in the case of Slag filter ($r = 0.93$).

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Relief Information Renewal in GIS Data Collection with LiDAR Method

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Aleksandras Stulginskis University

Abstract

Objective of this research is to identify which relief data is better for renewing GIS data collections: horizontals accumulated with LiDAR method or horizontals formed by analogical method.

To find out this objective accuracy analysis model of surface elevation formed by different methods was created. Research was carried out in three stages: 1) Choose territory and collect spatial data; 2) Data processing; 3) Analysis of data. Research object is relief of the part of village Pypliai which is in Kaunas district. In respect of relief it is varied, different expressiveness place, situated by river Nemunas.

After the comparison of elevation data got by geodetic and analogical methods was estimated that total intersect area is 0,9581 ha (32% of all investigative territory). When compared elevation model made by geodetic method and LiDAR method, was estimated that elevation intersects in 1,2762 ha of the territory (43% of all investigative territory). This research demonstrates that LiDAR elevation data is more accurate than analogical model data. Nevertheless, utmost 10 meters error is considerable while comparing to geodetic model data, it occurs 10 times of 74 cases of comparison.

Key words: GIS, horizontals accuracy, LiDAR, mapping, relief, renewal.

Introduction

Analogical horizontal display method which signify relief introduced in the end of nineteenth century in Lithuania (Kazakevičius 2000, 2001). Topographical maps of scale 1:10 000 have published since 1955 to 1991. Relief of these maps is used till now. It is digitizing, copying, and moving into a database (eg GDR50LT). Digitized horizontal are world widely usable for creating digital terrain models now (Kumetaitičienė 2005).

With the development of computer equipment now is popular to use digital data accumulation and processing methods (Ruzgienė 2008). The newly created and recently put in to use of gathering geographic information about dimensional earth’s surface effective laser scanning (probing) from air method LiDAR (Light Detection and Ranging). Main reason for using LiDAR systems is that LiDAR is able to capture significant height (usually pitch is determined after processing) data arrays in a short period of time (Žalnierukas et al. 2006). Initial data collected by LiDAR system is not only the information about earth’s surface geodetic elevation, but also about other natural and man-made objects in earth’s surface (e.g. vegetation, buildings, etc.). LiDAR technology helps to develop such projects: the topographic data collecting, updating and maintaining cadastral data, tourism, wood register, and inventory of known and unknown surfaces, power line maintenance and planning, GIS and others (A.Aleknavičius et al. 2008), development of digital terrain models of oceans, coastal zones and wetlands (Ruzgienė 2008), exploration of high-density areas of tall buildings (Barazzetti et al. 2007). LiDAR also used in mapping surface of Mars (Miller 2008) and analyzing earthquake possibility (Cunningham et al. 2006), ground deformations and landslides (Satkūnas et al. 2008).

In 2009 – 2010 remote LiDAR scanning was carried out in whole of territory of Lithuania. Aim of the latter scanning was to develop LiDAR database in form of location (Digital Terrain Model, further on – DTM) data and land surface (Digital Surface Model, further on – DSM). In addition, LiDAR database was used in production of orthophotographic maps. The required density of laser points was 0,5 point per square meter. Expected absolute accuracy – 0,50 m, measured and verified on hard surface (National 2010).

LiDAR remote scanning DTM and DSM data quality is acceptable and meets the quality level required for the project. However, is this data accurate at places of different expressiveness? And what are the noticeable changes when comparing old cartographic information and LiDAR data with geodetic measurements?

Therefore, the objective of this research is to identify which relief data is better for renewing GIS data collections: horizontals accumulated with LiDAR method or horizontals formed by analogical method.

Research methods

Research object is relief of the part of village Pypliai which is in Kaunas district (Figure 1). In respect of relief it is varied, different expressiveness place, situated by river Nemunas. The following initial data was used: cartographic data base at scale 1:10 000 (KDB10LT ) horizontals, laser scanning point data set and horizontals created in geodetic method (topographic map ). All horizontals have a step of 5 meters. Digital orthophotographic map sheet „Raudondvaris“ (the nomenclature 57/37) at scale 1:10000 (ORT10LT ) was used as additional tool.
Research was carried out in three stages:
1. Choose territory and collect spatial data
2. Data processing
3. Analysis of data

The following scientific research methods were used to create an accuracy analysis model of surface elevation formed by different methods: analysis of cartographic material, logical thinking, modeling, comparison and generalization of the data and graphic representation.

ArcGIS 10, GeoMap software was used to carry out the research and Excel software for data processing.

**Results of research**

In first step of this research model was created. It was decided that the following criteria should be evaluated if is necessary to identify areas where horizontals height intersects: horizontals height, size of area, elevation errors, expressiveness of relief, land use. Therefore the main problem was to determined territories and areas where horizontals intersect and vary. Geographic information systems (GIS) as one of the tools for solving this problem was chosen.

6.94 ha territory at Pypliai village had been measured by geodetic devices. Only 2,950 ha of it were used for the research. That territory was chosen because it had miscellaneous natural situation (open and wooded terrain) and an expressive relief.

First of all, primary data had been processed by GeoMap program. It is the only program which can identify primary field measurements. Horizontals were created at the territory of research by using 215 measured points. 15 horizontals with a step of 5 meters had been drawn automatically. File of surface scheme is in a DWG/DXF vectorial data format. This format is common in Computer Aided Design (CAD) software – “Autodesk” (Govozov 2008). The main research had to be done with ArcGIS system so it was a must to convert data from CAD to GIS format (Shapefile – vectorial data format which uses SHP, SHX, and DBF files (Govozov 2008)). It had been done in the first step of model creating.

Analysed spatial data were processed at second stage. It was done with the help of various tools of software „ArcGIS“. Territory of interest was allocated (new shapefile was created) to avoid loading the software. Only 2,950 ha of it were used for the research. That territory was chosen because it had miscellaneous natural situation (open and wooded terrain) and an expressive relief. Horizontals made by Geodetic, LiDAR and Analogical method in territory of interest were created. It was done with the help of one of analysis tools “Clip”. All of them are in three vectorial data layers. It is difficult to analyse accuracy if there are just vectorial elevation data. Therefore it was used Spatial Analyst tool “Topo to raster”. This tool interpolates raster surface from line. Raster elevation models of territory of interest were created. It was done to all three layers separately. New raster elevation models were classified into 12 elevation zones. They fit the interval of horizontals. For instance, the lowest elevation interval (25) includes 22,32 to 25 meters value. The highest elevation interval (80) includes 75 to 80 meters value. After all raster elevation models of relief mapping had been made, it was cared out that they do not intersect. There are visible differences not only in flat and hilly terrain but also in wooded and open area.

Geodetic method is considered the most accurate so it will be the basic data in further research. LiDAR and analogical methods had been compared in order to identify which method is more familiar with the basic one (geodetic vs. analogical and geodetic vs. LiDAR). It had been done in the final step - analysis of data. ArcGIS analysis tool “Intersect” to carry out analysis was chosen. It computes a geometric intersection of the input features (ArcGIS 2012).

First comparison is between geodetic and analogical methods (Figure 2 A and B). During analysis of the investigative 2,950 ha territory was estimated that there are 13 zones which elevation intersects more or less. 2 territories intersect in two elevation zones but there is discrepancy in elevation zone of 50-55 meters. Total intersect area is 0,9581 ha. It is 32 % of all investigative territory (Figure 2, A). The smallest area is 0,2 m2, the largest – 0,5187 ha. Major part of intersecting area is in flat and open territories. The most of discrepant territories are in steep slope overgrown with deciduous woods.
When compared elevation model made by geodetic method and LiDAR method, was estimated that elevation intersects in 1,2762 ha of the territory. It is 43% of all investigative territory (Figure 2, B). They are spread in 12 zones. There is an intersection in every elevation zone. The largest intersection areas are in flat and open territory (0,3659 ha) and in sparse forest territory with a slight slope (0,4982 ha). There are many minor intersections of small area in a slope overgrown with woods.

In the research was cared out that there are three +15 meters errors in analogical elevation model. It means that there are territories which elevation is 15 meters higher than in geodetic measurements. Most common error value (Mode) is 5 meters. It occurs 30 times and it is positive or negative. Error that is +10 meters occurs 17 times and it is positive in all cases. There had been estimated 24 cases of absolute intersection, i.e., when both comparing models completely match each other. Average elevation of all errors is 4,4 meters.

While comparing LiDAR and geodetic data discrepancy, it was measured that utmost discrepancy of both models is 10 meters and it occurred 10 times. They are both positive and negative. 36 errors consist of 5 meters discrepancy. Both models intersect completely in 28 cases, i.e., error valued at 0. Average elevation of errors is 0,95 meters.

In summary, maximum error of 15 meters was estimated in analogical model. Same model had much more 10 meters errors (17 and 10 cases). Mode of both models is the same – 5 meters, but it is more frequent in laser scanning model (36 and 30 cases). Also same model had more absolute intersection cases (28 and 24 cases). Average elevation of errors is significantly lower in laser scanning model (0,95 and 4,4 meters). Due to all results mentioned above, it can be confirmed that laser scanner elevation data is more accurate than analogical model data. However, utmost 10 meters error is considerable while comparing to geodetic model data, it occurs 10 times of 74 cases of comparison.

Conclusions

After the comparison of elevation data got by geodetic and analogical methods was estimated that total intersect area is 0,9581 ha (32% of all investigative territory). Utmost elevation discrepancy is 15 meters, Mode – 5 meters.

When compared elevation model made by geodetic method and LiDAR method, was estimated that elevation intersects in 1,2762 ha of the territory (43% of all investigative territory). Utmost elevation discrepancy is 10 meters, Mode – 5 meters.

LiDAR elevation data is more accurate than analogical model data. Nevertheless, utmost 10 meters error is considerable while comparing to geodetic model data, it occurs 10 times of 74 cases of comparison.
References


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Reduction of Environmental Impact Using Timber Bridges on Forest Roads

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Transilvania University of Braşov, Romania

Abstract

Timber represents a common used material in all the activities. There are references which attest its utilization as a construction material since the early known human history. Recent development solutions reintroduce the wood in construction by developing composite materials. The same fact applies to bridges and culverts, but the raw timber is still used, and, in some adequate conditions, the realized constructions present a long life expectancy. In Romania, forest roads are, in their majority, endowed with concrete bridges and culverts. Also, due to the well represented hydrography, their construction and maintaining represents a major cost component in the overall cost of the road. Most of them are no longer technically effective and represent a danger in the transportation activity, especially since the utilized means are realized for increased transport capacities. By comparison with traditional technical solutions (concrete bridges and culverts), timber may present a reduced life expectancy as a construction material. However, its availability at the construction site may compensate in the cost analysis. Also, there cannot be neglected the eco-efficiency of the construction when the timber is used as base material, especially in the context in which traditional concrete solutions are realized involving increased Green House Gases (GHG) emissions. In this context, in the paper are analyzed the existent and some proposed timber solutions for bridges and culverts – forest roads, with regard to the overall involved components with special focus on the costs and GHG emissions (CO₂).

Key words: timber, bridges, assessment, efficiency, GHG emissions.

Introduction

Wood as a structural engineering material and its use in bridge construction applications.

Forest roads are, for the moment, poorly developed in Romania (Varjoghe, 1996; Bereziuc et al., 2006; Bereziuc et al., 2011), but the future perspectives consider the endowment of forests with transportation infrastructure, represented mostly by forest roads (Bereziuc et al., 2011), as a necessary requirement for sustainable forest management, especially for the extraction of its main product – the wood (Oprea, 2008). Also, by increasing forest accessibility, the use of new environmentally sound timber harvesting technologies such as short-medium distance cable yardsers will be enabled (Borz et al., 2011).

Currently, wood represents one of the most used structural materials in construction activities and industries. Its utilization has a long tradition, and, practically, it is used from the beginnings of the mankind. Timber imposed itself as a structural construction material due to some specific properties. By comparison with other structural materials such as steel, concrete or polymers, timber presents the advantage of being a sustainable natural fast growing construction material. It presents, also, some disadvantages like the variation of quality and properties both at intra-species and interspecies level (Brischcke et al., 2012). Similarly, timber bridges, as engineering constructions, have their own old tradition as well as their advantages and disadvantages. Thus, the first attested timber bridges where realized more than 5000 years ago as crossing constructions over the Nil River (Gerold, 2001). After that, timber was used on a large scale for bridge construction, and, currently, many of these constructions are still in use. In Australia for example, there exists around 29,000 timber bridges from which a third present ages greater than 50 years (Choi et al., 2008). The main issue when dealing with timber bridges is represented by timber ageing followed by its degradation (Choi et al., 2008). Due to this problem, a lot of the existing timber bridges around the world, need, currently, reparation. In this context, there was stated the problem of developing cheap and innovative solutions (Gutkowski et al., 2008), both, on the American continent (Ritter, 1992; Duwadiand and Ritter, 2001), as well as in Central and Eastern Europe (Gutkowski, 1997; Gutkowski, 1999).

Deterioration of the existent timber structures may be the result of the increased service loads, ageing and biological attacks. Biological deterioration of the timber structural elements due to enzymes diffusion is a phenomenon similar to different induced corrosion mechanisms on steel and concrete elements (Yail and Kent, 2010).

Usually, there are used different species and essences for timber bridges construction such as pine, Douglas fir, oak and cedar (Wood handbook – wood as an engineering material, 1999). Also, for protection purposes is frequently used the creosote which may assure a technical life of up to 40 years (Peck et al., 1974).

By comparison with the current technical solutions (mostly concrete bridges), timber presents the advantage of being a renewable material, having no or small impact on the environment, and being characterised by local availability in most of the world’s regions. In this context, timber bridges may represent suitable solutions for forest roads if the economic and environmental impact is to be considered, and since the current technical solutions use the concrete as a construction material, studies regarding the perspective and opportunities of wood re-introducing in road structural designs should be re-assessed.

Traditional constructive solutions for decks include the utilization of reinforced concrete beams, which are usually realized in specialized manufacturing plants. Therefore, when dealing with long transportation distances, the potential damaging effect on the environment is even greater. By comparison, timber decks use the woody raw material which could be found locally or at short distances, as well as some minor manufactured assemblies. Timber decks may be realized using several constructive solutions as shown in Figure 1.
The objective of study

The objective of this study was to perform a comparison between the timber and traditional bridge technical solutions which usually use reinforced concrete beams for deck construction, in order to reveal if the first technical solutions (timber decks) may represent a viable solution with application in forest roads construction, in the context of technical, economical and environmental sustainability. Because the compared constructive solutions differ only by the deck type (wood, respectively concrete), both, the costs and environmental impact (in terms of CO₂ emissions) were analyzed only for these constructive assemblies.

Research methodology

Lately, the efficiency of a product is assessed by using the life cycle assessment (LCA) which is a scientific methodology, enabling the identification and quantification of the environmental inputs and outputs associated with a product in relation to its main function, and which considers all stages of its life cycle (Frenette et al, 2012). LCA includes the study (development) of four phases (Finkbeiner et al., 2006): definition of goal and scope, life cycle inventory (LCI), life cycle impact assessment (LCIA) and interpretation.
In order to assess the life cycle of a product, both, the functional unit and the system’s (study) boundaries have to be identified (defined). This study applies the LCA methodology in order to assess the technical, economical and environmental performances of timber decks by comparison with concrete reinforced beams decks. Therefore, the LCA methodology was applied (performed on) in order to assess the performances of two constructive solutions as well as to distinguish between them in order to choose the most appropriate one.

Despite the fact that there exist different constructive solutions for the abutments, in Romania, the last ones are usually realized using the same constructive solution – cast-in-place concrete abutments (Bereziuc et al., 2011). Therefore, for this study purpose, the comparisons between the two studied bridge types was realized at deck level, which, in the present study, constituted the functional unit having the main role of assuring the communication infrastructure continuity over an encountered obstacle (river). As a consequence, the functional unit represents all the necessary assemblies for the deck realization, and for comparison purposes there was used the linear meter of construction. The functional unit’s functions refer also to the realization of traffic in safety conditions, reason for which strength calculations were performed for an adequate dimensioning of the two constructive solutions. For these purposes there were used the calculus conveys which are specific to the Romanian forest roads - A10 S30 and ATF25 respectively (Bereziuc et al., 2011).

In this study, the boundaries of the analysed system referred to the direct impact generated by the construction and maintenance of the analysed technical solutions. The impact analysis refers directly to the resources extraction, manufacturing processes, transport processes and construction processes.

The life cycle inventory (LCI) analysis is usually done in order to evaluate the quantities of material, substance and energy going in and out of a system, during its life cycle, for a specific functional unit (Jolliet et al., 2005). Due to the fact that such an inventory requires an extensive work (Frenette et al., 2010), for the purpose of this study it was used the information provided by Athena Institute (Cement and Structural Concrete Products, 2005; Cradle-to-Gate Life Cycle Inventory, 2002; A Cradle-to-Gate Life Cycle Assessment of Canadian Softwood Lumber, 2002) for the assessment of required energy inputs and outputs, as well as data available in other sources (data regarding the required quantities of construction materials was extracted from decks’ designs using the AutoDesk Civil 3D functionalities).

Results

Description in terms of required materials, involved costs and CO$_2$ emissions for the compared constructive solutions.

Specifications regarding the required materials, costs and CO$_2$ emissions involved in the realization processes of the two constructive solutions which make the object of the comparison (traditional concrete beams decks and simple beams timber decks – Figure 1) are presented in Tables 1 and 2. For each constructive solution was specified the main dimensions as well as the considered measurement units. For comparison purposes, there was chosen a span of 8 meters and a width of 5 meters for each technical solution, dimensions which are common on the forest roads from Romania.

Table 1. Pre-manufactured beam concrete deck – required quantities, involved costs and CO$_2$ emissions: 8 meter span, 5 meter width

<table>
<thead>
<tr>
<th>Specifications</th>
<th>Measurement unit</th>
<th>Required quantities / Involved costs / CO$_2$ emissions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Quantities</td>
</tr>
<tr>
<td>Concrete for the main pre-manufactured beams</td>
<td>m$^3$</td>
<td>10.00</td>
</tr>
<tr>
<td>Concrete for the crossbars and ramps</td>
<td>m$^3$</td>
<td>2.90</td>
</tr>
<tr>
<td>Cast-in-place concrete</td>
<td>m$^3$</td>
<td>2.50</td>
</tr>
<tr>
<td>Roadway concrete (including roadway grading concrete)</td>
<td>m$^3$</td>
<td>3.56</td>
</tr>
<tr>
<td>Reinforcement steel bars</td>
<td>kg</td>
<td>1520.00</td>
</tr>
<tr>
<td>Metallic parapets</td>
<td>kg</td>
<td>680.00</td>
</tr>
<tr>
<td>Casts (lumber)</td>
<td>m$^3$</td>
<td>19.00</td>
</tr>
<tr>
<td>Hydro-insulation (asphaltic film)</td>
<td>m$^3$</td>
<td>42.00</td>
</tr>
<tr>
<td>Materials transport</td>
<td>Kilometric tonnes</td>
<td>1200.00</td>
</tr>
<tr>
<td>Pre-manufactured materials assembling at the</td>
<td>Tonnes</td>
<td>25.00</td>
</tr>
<tr>
<td>construction site</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>9031.00</td>
</tr>
</tbody>
</table>

In Table 1, quantities were evaluated by considering the necessary materials for realizing each sub-assembly of the concrete deck. The most increased material necessities are those which refer to the concrete. Important quantities of steel are required in order to ensure the construction stability. Also, the needed materials are to be procured and transported from increased distances by comparison with the second constructive solution (Table 2), which presents the advantage of the raw material availability in proximity of the construction sites. The advantage of the constructive solution presented in Table 1 resides in the use, in majority, of the mechanized means for construction. However, some manual labour is required, especially for small sub-assemblies realization. Also, casts involve the transport of the
necessary material (lumber) due to the fact that this product is not available at the construction site. The overall solution needs materials which are not available at the construction site or in its proximity, fact which imposes the realization of transport on increased distances. Usually lumber, asphaltic film and other auxiliary materials are available at closer locations from the construction site, but the pre-manufactured concrete beams and the materials needed for parapets are available only at specialized plants or sellers.

Costs presented in Table 1 where calculated by considering the material prices available on the Romanian market whereas the CO$_2$ emissions were calculated using different sources. There can be observed that the greatest CO$_2$ emissions are those resulted from iron ore extraction and steel manufacturing industries. This could represent a problem if there is considered the necessity of reconstructing the bridges which are currently in a non-serviceability state since these constructions are very well represented on the forest roads from Romania (Varjoghe, 1996).

### Table 2. Timber deck – required quantities, involved costs and CO$_2$ emissions: 8 meter span, 5 meter width

<table>
<thead>
<tr>
<th>Specifications</th>
<th>Measurement unit</th>
<th>Quantities / Involved costs / CO$_2$ emissions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Round-wood for main beams</td>
<td>m$^3$</td>
<td>8.00 / 232.00 / 128.00</td>
</tr>
<tr>
<td>Round-wood for bridge flooring</td>
<td>m$^3$</td>
<td>4.80 / 139.20 / 76.80</td>
</tr>
<tr>
<td>and crossbars</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Round-wood for parapets</td>
<td>m$^3$</td>
<td>0.80 / 23.20 / 12.80</td>
</tr>
<tr>
<td>Transport</td>
<td>kilometric tonnes</td>
<td>80.00 / 40.00 / 12.00</td>
</tr>
<tr>
<td>Auxiliary metallic materials</td>
<td>kg</td>
<td>120.00 / 360.00 / 312.00</td>
</tr>
<tr>
<td>Labour</td>
<td>hours</td>
<td>680.00 / 2720.00 / 0.00</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>3514.00 / 541.00 / 0.00</td>
</tr>
</tbody>
</table>

Similarly to Table 1, in Table 2 are presented the necessary quantities of material, the involved costs as well as the CO$_2$ emissions involved by the realization of the timber deck constructive solution. The necessary quantities resulted from the specific resistance-dimensioning calculus which was done according to the Romanian standards (Bereziuc et al., 2011). Thus, there were considered the calculus conveys A10, S30 and ATF 25. Costs for the timber deck realization were estimated according to the average prices for the wood assortments (round-wood for the main beams, round-wood for bridge flooring and crossbars, round-wood for parapets) in case of the sub-assemblies which required wood for their realization. In the case of transport, shorter distances were considered due to the resource availability in closer positions relative to the construction site. Costs for the auxiliary metallic materials were estimated as averages whereas the labour costs were calculated according to Romanian legislation.

CO$_2$ emissions for round-wood production included all the processes involved in timber harvesting. Due to the fact that some assortments were required in increased length conditions, for timber harvesting were considered mechanized means. All the emissions were calculated by considering the motor gasoline consumption rates and the available conversion factors (Markevitz, 2006). Similarly to the first constructive solution, the greatest emissions are those resulted from iron ore extraction and steel manufacturing industries. For instance, in case of timber constructive solution the last mentioned emissions represented more than half from the total emissions (58%).

### Comparison in terms of costs and CO$_2$ emissions of the constructive solutions

Economic feasibility is one of the main used tools when trying to assess which technical solution should be used. If the two studied constructive solutions are compared, there results that the timber deck constructive solution is cheaper than the first one, presenting, by comparison, a reduced investment. The investment economy resides mainly in the materials and the acquisition costs economies. Concrete pre-manufactured beams are highly processed products whose realization involves cost intensive processes and materials, leading to increased costs per measurement unit. The same applies to reinforcement steel bars which come to the market at high prices for the same reasons. By comparison, wood represents reduced costs and, in general, a better availability and accessibility around the construction sites in Romania. Production processes in the last case are simpler and fewer, fact which leads to the mentioned reduced costs. Also, timber decks may attain their functionality with considerable reduced quantities of material if compared with concrete reinforced beams decks.

For this paper purpose, the environmental impact was assessed by considering the CO$_2$ emissions involved in different processes: raw material extraction, manufacturing, transport and site construction. If the two solutions are to be compared, the last one is far superior by the reduction of the CO$_2$ emissions with up to 95%. This carbon economy results from the utilization of a renewable resource as well as from the simplified and reduced processes involved in the resource extraction and processing. As presented in Table 1, the main emissions in the case of the first constructive solution are those from concrete and steel manufacturing which are responsible for up to 90% from the overall budget. The same applies to the second constructive solution, but the difference between solutions resides in the necessary quantities of steel industry products.

Despite the fact that the Romanian literature does not provide specific values regarding the life expectancy for the concrete and timber bridges from the forest roads, experience has shown that a typical concrete bridge has a serviceability of up to 50 years. Also, by comparison, and depending by the used protection measures, a timber bridge may last for 15 to 20 years. This leads to a serviceability reduced with up to 60-70% in case of the timber deck
constructive solution. For this reason most of the engineers have chosen in the past the realization of timber bridges using the first solution. In the meantime, environmental concerns started to show up, especially since Romania signed the Kyoto’s Protocol. Therefore, if the second constructive solution will be used in the future, important economies may be attained in the carbon balance. Also, there cannot be neglected the economical aspect. For example, the second constructive solution may be almost 2.6 times cheaper than the first one, and in adequate protection conditions, it can last almost half from the first one’s serviceability period. By considering this last aspect as well as that referring to the costs and CO₂ emissions, the timber may be seen as a material with increased potential in the forest roads crossing works construction.

Conclusions

Reintroduction of timber bridges on forest roads from Romania may generate substantial benefits in what concerns the technical, economical and environmental issues, because the associated costs, involved technology as well as the environmental impact are much lower by comparison with traditional reinforced concrete decks, as shown by this paper. In fact, costs of realizing timber decks represent only 38% from those corresponding to reinforced concrete beams decks, this way generating an important economy of capital and providing a viable cost-effective solution, especially in the context in which most of the forest roads bridges have to be repaired in the closer future. On the other hand, Romanian strategy regarding the development of forest sector forecasts the development of forest road network from the current density index of about 6.5 m ha⁻¹ up to 20 m ha⁻¹. By considering the fact that all the roads to be constructed in the future will be located mostly in the mountainous region and by considering that the proportion of bridges within the forest will be approximately the same, this means that an important amount of crossing works will be required.

Steel manufacturing industry is one of the industries which generate important quantities of CO₂ emissions. Furthermore, the traditional technical solutions (reinforced concrete decks) do require important quantities of steel in their realization, fact which in the application of future national strategy regarding the forest roads development may generate some problems because of the iron ore extraction and manufacturing as well as concrete manufacturing. In fact, the CO₂ emissions for realizing a traditional reinforced concrete deck are about 18 times greater by comparison with a timber deck solution. This could mean that about 18 decks may be constructed for the same carbon emissions when choosing the timber as construction material.

In many construction applications, aesthetics represent an important point to be achieved when the designs are implemented in practice. Many of the Romanian forests are designated as protected areas and much more of them are used also as touristic locations. Since the forest roads represent, maybe, the single access infrastructure to these forests, the use of wood as construction material should be considered also from the aesthetic point of view.

Timber decks have also some important drawbacks such as the more reduced serviceability life by comparison with traditional solutions (up to three times smaller) as well as reduced possibilities related to the material disposal when serviceability life was attained (treatments with creosote etc.). The first issue may be compensated by the local availability of the raw material as well as by simpler technologies for construction, whereas the second one may still represent a problem. However, the burning of the resulted woody material may be a solution in this last case.

Finally, the main conclusion which could be extracted from this study results is that that the use of timber decks as constructive solutions for forest roads bridges may be a present and future sustainable solution in what concerns technical, economical and environmental issues because they are easier to construct, cheaper than concrete decks (about 2.6 time cheaper) and environmentally friendly (about 18 times lower CO₂ emissions).

References


Abstract

The total number of bird species after commercial thinning’s remained similar, but the total bird abundance decreased by 1.39 times. We registered 33 bird species totally. Analysing species, that during census made 4 and more registrations (17 species), the abundance of 64.7% species decreased, 29.4% - increased, 5.9% - remained similar. Statistical significant decrease of relative bird abundance after thinning’s were registered among the ground nesters and the top canopy nesters. The abundance of the hole nesters increased close to significant, however the relative abundance of the bottom canopy nesters remained similar. The abundance of migrants significantly decreased and opposite sedentary birds close to significantly increased. The abundance of the vertebrate and the invertebrate predators, the herbaceous significantly decreased as well as outside forest food searchers showed close to significant decrease. Among most abundant invertebrate predators, mostly negative abundance change were observed of the canopy and the air searcher guilds. The abundance of the ground searchers remained similar as well as the bark surface searchers increased close to significant.

Introduction

Forest management makes huge impact to bird communities (Brazaitis, 2003, Brazaitis at al. 2005). Lithuanian society is very sensitive to the facts of damage and destroy of nature, periodically appeared in the press, and constantly rise higher nature conservation requirements. We need find economically and ecologically acceptable ways to minimize negative impact forest management to biodiversity and birds. Forest thinning’s are one of routine types of forest management that rise discussions about negative impact on birds. It is important identify forest thinning’s negative aspects and clarify methods to prevent it. In North America the impact of commercial forest thinning’s analysed in numerous studies (Hayes et al., 1997, 2003; Hunter, 2001; Hagar et al., 2004; Kalies et al., 2010). However in Europe this question is still unclear. Forest thinning’s decrease the number of trees in the stand, promoting mostly perspective. Wood volume consumed by thinning’s may reach the volume of final felling’s (Juodvalkis ir Kairiūkštis, 2009), in fact it is between 30-40%. This shows that thinning’s are the factor that affects extensively forest ecosystems.

Commercial thinning’s have huge impact on bird communities. Wedeles and Van Damme (1995) concluded that negative impact is connected with simplified forest structure, decrease of noble hardwood and snags. Most of studies confirm that structural complexity of the stand vertical canopy density and height diversity are important factor positively affecting bird abundance (Welsh and Lougheed, 1996;Willson and Comet, 1996, Thompson et al. 2003). Forest thinning’s creates many short and long term changes that mostly significant – decreased tree density and increased amount of stand gaps (Artman, 2003; Agee and Skinner, 2005; Hayes et al., 2003; Harrod et al., 2009). Purposeful structural formation might increase wildlife diversity (Spies and Franklin, 1991; Hayes et al., 1997). One of positive mechanism is promoted development of undergrowth due to increased light intensity (Wilson and Carey, 2000; Garman, 2001; Marozas at al. 2005; Homayck et al., 2005). Unless might increase complexity of habitats, that favour environment to wildlife, commonly commercial thinning’s the number of species didn’t increase (Wilson et al. 2009). Scientific comparison of bird communities between natural and cultural stands concluded that mostly significant differences are on young age, but the differences disappear in stand maturity age (Hansen et al. 1995; Barber et al. 2001; Thompson et al. 2003) except hollow nesters (Land et al. 1989).

Up to now stand thinning’s aimed commercial aspects utilizing natural processes. The aim of this study was to analyse how bird communities are affected by commercial thinning’s.

Materials and methods

The study was performed surveying bird communities in the same stands years before and after (next year) commercial thinning’s. Commercial thinning’s were made during non-breeding period. We used standard line transect method (Bibby and Burgess 1992; Пыриле и др. 1986). Line transect were situated along mid of forest stand that planned perform commercial thinning’s, mapping it on GPS devise to repeat survey exactly on the same route next years. Birds were registered separately in and out 50 m-with belt, and not registered outside surveyed stand. The average speed of bird count was 1.5 km/h. We registered all birds that were noted by sound and vision.

The study was made in central, south western part of Lithuania, Kaunas, Marijampole and Sakiai forest enterprises. We selected various tree dominated stand to get comprehensive view studied question. The study performed in medium aged stands (40-60 yrs.) that are not mature for final felling.

Results

The bird species and community level

The total number of bird species after commercial thinning’s remained similar (T=0.01; p<0.92), however, the total bird abundance decreased by 1.39 times (T=3.1; p=0.006). During the counts we registered typical for medium-aged forest bird species. We registered 33 bird species totally and 17 species more than 4 times. Mostly abundant was
the Chaffinch. More than 20 registrations were of the Wood warbler, the Robin, the Goldcrest, the Tree pipit, the Blackbird, the Wren (Table 1). Other five species were registered 10-20 times: the Song thrush, the Great tit, the Blackcap, the Chiffchaff, the Jay. Finally, 21 species were registered less than 10 times.

Analysing species, that during census made 4 and more registrations (17 species), the abundance of 64.7% species decreased, 29.4% - increased, 5.9% - remained similar. Statistically significant (or close to significant) decrease of abundance observed of the Chaffinch (T=2.56; p<0.02), the Wood warbler (T=1.94; p<0.067), the Robin (T=1.69; p<0.11), the Blackcap (T=2.35; p<0.03), the Jay (T=2.61; p<0.02), the Pied flycatcher (T=1.83; p<0.08) and the Woodpigeon (T=1.74; p<0.096). Statistically significant (or close to significant) increase of abundance observed of the Great tit (T=-2.32; p<0.03), the Wren (T=-2.44; p<0.024), the Great spotted woodpecker (T=-1.83; p<0.082), the Woodpigeon (T=1.74; p<0.096). Statistically significant (or close to significant) decrease of abundance observed of the Chaffinch (T=2.56; p<0.02), the Wood warbler (T=2.35; p<0.03), the Pied flycatcher (T=1.83; p<0.08) and the Red-breasted flycatcher (T=1.39; p<0.19) abundance before and after stand management didn’t significantly differ.

Table 1. Bird species abundance before and after commercial thinning’s

<table>
<thead>
<tr>
<th>Bird species</th>
<th>Bird abundance</th>
<th>Total registrations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before thinnings</td>
<td>After thinnings</td>
</tr>
<tr>
<td>Chaffinch Fringilla coelebs</td>
<td>72</td>
<td>45</td>
</tr>
<tr>
<td>Wood warbler Phylloscopus sibilatrix</td>
<td>30</td>
<td>13</td>
</tr>
<tr>
<td>Robin Erithacus rubecula</td>
<td>24</td>
<td>14</td>
</tr>
<tr>
<td>Goldcrest Regulus regulus</td>
<td>15</td>
<td>22</td>
</tr>
<tr>
<td>Tree pipit Anthus trivialis</td>
<td>20</td>
<td>14</td>
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<tr>
<td>Blackbird Turdus merula</td>
<td>16</td>
<td>14</td>
</tr>
<tr>
<td>Wren Troglodytes troglodytes</td>
<td>4</td>
<td>17</td>
</tr>
<tr>
<td>Song thrush Turdus philomelos</td>
<td>10</td>
<td>9</td>
</tr>
<tr>
<td>Great tit Parus major</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>Blackcap Sylvia atricapilla</td>
<td>13</td>
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</tr>
<tr>
<td>Chiffchaff Phylloscopus collybita</td>
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<td>6</td>
</tr>
<tr>
<td>Jay Garrulus glandarius</td>
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<td>2</td>
</tr>
<tr>
<td>Pied flycatcher Ficedula hypoleuca</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>Woodpigeon Columba palumbus</td>
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<td>1</td>
</tr>
<tr>
<td>Crested tit Parus cristatus</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Marsh tit Parus palustris</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>Tree creeper Certhia familiaris</td>
<td>2</td>
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</tr>
<tr>
<td>Great spotted woodpecker Dendocopos major</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Redstart Phoenicurus phoenicurus</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Lesser whitethroat Sylvia curruca</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Red-breasted flycatcher Ficedula parva</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Nuthatch Sitta europaea</td>
<td>0</td>
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<td>Green sandpiper Tringa ochropus</td>
<td>1</td>
<td>1</td>
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<td>Coal tit Parus ater</td>
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<td>Golden oriole Oriolus oriolus</td>
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<td>Hazel grouse Bonasa bonasia</td>
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<tr>
<td>Dunnock Prunella modularis</td>
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<tr>
<td>Mistle thrush Turdus viscivorus</td>
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<tr>
<td>Whitethroat Sylvia communis</td>
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<td>Spotted flycatcher Muscicapa striata</td>
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<td>Willow tit Parus montanus</td>
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<td>Blue tit Parus caeruleus</td>
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<td>1</td>
</tr>
<tr>
<td>Siskin Carduelis spinus</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Total:</td>
<td>260</td>
<td>202</td>
</tr>
</tbody>
</table>

The bird guild level
Statistical significant decrease of relative bird abundance after thinning’s were registered among the ground nesters (T=2.56; p<0.02) and the top canopy nesters (T=2.87; p<0.00) (Fig. 1). The abundance of the hole nesters increased close to significant (T=1.88; p<0.074), however the relative abundance of the bottom canopy nesters remained similar (T=0.72; p<0.48).

The analysis of the birds in relation to their migration status showed different results (Fig. 2). The abundance of migrants significantly decreased (T=3.48; p<0.0024) and oppose sedentary birds close to significantly increased (T=1.58; p<0.13).

Under the feeding habits, different guilds also showed various respond to stand management (Fig. 3). The abundance of the vertebrate (T=2.61; p<0.002) and the invertebrate (T=2.61; p<0.002) predators, the herbaceous (T=2.76; p<0.02) significantly decreased as well as outside forest food searchers (T=1.67; p<0.1) showed close to significant decrease. Among most abundant invertebrate predators, mostly negative abundance change were observed of the canopy and the air searchers guilds (T=2.31; p<0.02). The abundance of the ground searchers remained similar (T=1.07; p<0.3) as well as the bark surface searchers increased close to significant (T=1.66; p<0.11) (Fig. 4).
Figure 1. The relative abundance change of ground nesters (left), top canopy nesters (mid), hole nesters (right) before and after commercial thinning’s.

Figure 2. The relative abundance change of migrants (left) and sedentary (right) bird species before and after commercial thinnings.

Figure 3. The relative abundance change of vertebrate predators (left), invertebrate predators (mid left), herbaceous (mid right) and outside forest food searchers (right) bird species before and after commercial thinning’s.

Figure 4. The relative abundance change of invertebrate predator guilds: canopy and air searchers (left), ground searchers (mid) and bark surface (right) bird species before and after commercial thinning’s.
Discussion

Our study show that after commercial thinning’s the number of species remained similar, but decreased the total relative bird abundance. The reasons of abundance decrease might be several. Most of studies confirm that the structural complexity of the stand vertical canopy density and height diversity are important factor positively affecting bird abundance (Welsh and Lougheed, 1996; Willson and Comet, 1996, Thompson et al. 2003, Brazaitis, 2003). Some studies shows that thinning might decrease the breeding success even if were removed small amount of wood. Breeding success decreased due to corvidae attacks, if the abundance of this predators were low that not have significant impact on breeding success (Ekman et al. 2001; Eggers et al. 2005a,b). High canopy density close to nest eliminate this effect. High visibility increase goshawk predation probability (Griesser and Ekman 2004; Griesser et al. 2006). Barber et al. (2001) found much higher nest predation rate in cultural vs. natural stands. Dense canopy enable avoid risk of predators (Hargis and McCullough 1984). The Capercaillie could avoid older thinned stands that has decreased density (Finne 2000) and normally selects natural stands (Zizas et al. 2012). Negative impact of thinning’s mostly significant in 1-4 yrs long period (Norton and Hannon, 1997; Hagar et al., 2004) and mostly negative effect is associated with elimination of ground covering arboreal vegetation (Hagar et al., 2004). Canopy specialists can negatively respond to intensive thinning’s (Norton and Hannon, 1997), as well as thinning’s might be more important factor for birds in some forest types (Christian et al. 1996).

In Mediterranean region were found that commercial thinning’s significantly increased bird species number but not affected total bird abundance (De La Montana 2006). The effect is explained by increase of habitat diversity. It’s important that possible to favour bird habitat and bird population status. Appropriate forestry management may increase biodiversity applying (a) increasing rotation age for selected stands; (b) increased stand vertical complexity and diversity by thinning’s, pruning, spatial variation, snag creation, residual tree retention; (c) introduction of new silvicultural systems aimed to increase landscape diversity and availability (Kerr 1999). Sometimes the effect on habitat structure of high density of ungulate species might be similar to thinning’s (Marozas et al. 2009). Stand management allows creating favourable condition for species and attracting them to new areas. By stand management possible to increase structural complexity that positively correlate with bird community parameters (Lindenmayer and Franklin 2002). However impossible favour all bird species by single silvicultural operation (Christopher et al. 2007). It’s still not analysed relation among certain habitat elements and bird species priorities that clogging aimed silviculture management to improve habitats for many species (Christopher et al. 2007). In some cases if stand management can’t create necessary habitat element, we simply can create them artificially (e.g. nest boxes, Maicas and Haeger 2004). Very often is recommended leave unmanaged (unthinned) areas for the species that abundance mostly negative affected by commercial thinning’s (De La Montana 2006). By hypothesis of Bailey and Tapperine (1998) shifted stand structure get more similar features to older stage areas, by this increasing habitat availability for late successional stage bird species.

Very important question is how commercial thinning’s affects bird species population status. However we do not consider commercial thinning’s have global negative effect to bird communities. Commercial thinning’s are (a) performed in relative small areas annually; (b) most of bird species have high habitat plasticity and inhabits much wider habitat types; (c) most rare species are typical forest late successional stage species. As commercial thinning’s year after year are performed in similar proportion of forest birds are adopted to such type of disturbance. Thinning’s have great impact on birds distribution but we do not have enough evidence to conclude it affects population status. Birds might have to change their breeding location inside forest landscape that might increase higher mortality.

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References


Apparent Volumic Mass Models for Pulpwood Norway Spruce Logs

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Abstract

The main purpose of this paper is the determination of the apparent volumic mass of spruce wood with bark for the pulpwood industry and, of the conversion factors necessary for making the conversions of mass to volume. The paper is also intent on determining the variation of the apparent volumic mass and on generating models that would allow an easier determination of it. In order to achieve this, four spruce populations from the Carpathian Mountains have been studied. The results obtained show a variation of the apparent volumic mass in anhydrous state between 308 and 418 kg/m$^3$, the average value being of 356 kg/m$^3$. Because the maximum absolute moisture value determined for freshly fallen wood was of 151%, the values of the apparent volumic mass and those of the corresponding conversion factors have been determined for an absolute moisture content of up to 150%. A regression equation which allows the determination of the apparent volumic mass according to wood moisture has been established for each population. The values of the volumic mass in anhydrous state have allowed the determination of the variation coefficients both at population level (5,1 ...9,2%) and at inter-population level (13,7%).

Introduction

The studied species is spruce (*Picea abies* (L) Karst.), one of the most common species in Romania where it covers about 1429500 ha, that is approximately 23% of the country's forests (Raport privind starea..., 2010). Also, spruce is one of the species which is very suitable for pulpwood industry. At present, the unit of measurement used for wood is the cubic meter. Moreover, certain beneficiaries verify the categories of wood by weighing expressed by tones or kilograms per cubic meter. Likewise, for an evaluation of costs and fuel consume at logging and transport, the mass unit becomes important (Kruch, 1994). Therefore, it is necessary that the conversion factors be established for the conversions of mass to volume. The physical unit which permits this is the apparent volumic mass (AVM) represented by the ratio of the wood mass to the volume determined under the same moisture content conditions. Because of the two anatomical elements - wood and bark - there are three different volumic masses: that of wood with bark, that of wood without bark and that of bark (Kruch, 1994). Wood properties determine the usability of wood as end products, in the pulp and paper industry, the wood panel industry and in solid wood manufacturing (Jaakkola et al. 2006). Density is the most widely used indicator of timber quality and affects the performance of sawn timber, suitability for panel products and pulp yields (Macdonald and Hubert, 2002).

Wood is a hygroscopic material, its moisture content being influenced at all times by the surrounding environment humidity and temperature, any change in these two elements triggering a change in wood moisture content (Vintila, 1942) and, implicitly, a change in its mass and volume. In the case of bound water, connected at the same time with humidity variation, wood undergoes huge dimensional and volumic variations being subject to contraction and swelling. Beyond the fiber saturation point, humidity has a great influence only on volumic mass, the dimensions and volume of wood remaining unchanged (Beldeanu, 2001). Spruce is considered to be a resinous species without duramen and with a fiber saturation point between 30 and 34% (Beldeanu, 2001).

The main purpose of this paper is the determination of the apparent volumic mass of spruce wood with bark for pulpwood industry in anhydrous state, at various levels of the moisture content, as well as of the conversion factors necessary for making conversions of mass to volume. Certain models or equations which might make the determination of the AVM easier are sought.

Research method

The research has taken place in four forest districts according to figure 1, on the platform of felling areas.
The dry volumic mass (DVM) of wood has to be known in order to determine the AVM at various levels of wood moisture content. Thus, sample batches have been established in all research locations and they have been used in order to determine the DVM of wood. The specific characteristics of pulpwood and the number of sample slices from each research location are presented in Table 1.

Table 1. The size of sample batches and the main characteristics of pulpwood

<table>
<thead>
<tr>
<th>Forest District</th>
<th>Average Diameter (cm)</th>
<th>No. of Wood Slices</th>
<th>Age (years)</th>
<th>Site Quality*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Miercurea Sibiului</td>
<td>21</td>
<td>29</td>
<td>110</td>
<td>I</td>
</tr>
<tr>
<td>Teliu</td>
<td>17</td>
<td>20</td>
<td>30</td>
<td>M</td>
</tr>
<tr>
<td>Măneciu</td>
<td>16</td>
<td>15</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Vidraru</td>
<td>16</td>
<td>30</td>
<td>35</td>
<td>M</td>
</tr>
</tbody>
</table>

*Site quality: I – inferior; M – medium.

A slice has been extracted from every sample piece. The slices have been weighed on the harvesting spot with the electric scales having an accuracy degree of 1 gram (fig. 2a). Afterwards, in the lab, the slices have been dried in the oven at a temperature of 103 ± 2°C (Vintilă, 1943; Ghelmeziu, 1944; Leahu, 1994; Dumitrașcu and Bădescu, 2009) until their mass remained constant, this representing the wood mass in an absolutely dry state or the wood mass in anhydrous state (fig. 2b). The absolute and the relative moisture of spruce wood have been determined on the basis of the difference between the mass values registered at green and dry slices.

Figure 2. a - the weighing of slices taken from sample pieces; b - the drying of slices in the oven

Then, the volume of slices in dry state has been determined. In order to do this, the slices have been likened to cylinders the height of which was equal to the average thickness of the slices and the base surface was equal to the cross cut surface of the slice. The thickness of the slices has been measured with the electronic calliper, the adopted thickness being the average of four determinations. In order to determine the surface of the slices, these have been photographed, their surface being determined with the help of the Autodesk Civil Services 3 program, by digitizing each photography (fig. 3).

Figure 3. The determination of: a – slice thickness; b - slice surface

Knowing the mass \( (m_o) \) and the volume \( (v_o) \) of slices in anhydrous state, the DVM \( (\rho_o) \) was determined for each separate batch with the help of the following relation:
\[
\rho_o = \frac{m_o}{v_o}
\]  

(1)

Based on the DVM of wood, the AVM for different values of the wood moisture content could be determined with the following relations (Beldeanu, 2001):

\[
\rho_u = \frac{\rho_o (100 + u)}{100 + K_{\alpha_c} \cdot u}, \text{ for } u < 30\% \quad \quad (2)
\]

\[
\rho_u = \frac{\rho_o (100 + u)}{100 + 30 \cdot K_{\alpha_c}}, \text{ for } u \geq 30\% \quad \quad (3)
\]

where:

- \(\rho_o\) - represents the DVM of wood;
- \(\rho_u\) - represents the AVM of wood at a \(u\) moisture content;
- \(u\) - represents the absolute moisture content of wood where the determination of \(\rho_u\) takes place;
- \(K_{\alpha_c}\) - represents the volumic swelling coefficient which has an average value of 0.38% in the case of spruce (Beldeanu, 2001).

The reference value of 30% represents the value of the absolute moisture content corresponding to the saturation point of the fiber.

The AVM determined in this way must always be accompanied by an indication of the wood moisture content at which the determination was made. On the basis of the AVM, the conversion factor corresponding to the following relation was determined:

\[
f_c = \frac{1000}{\rho_u}
\]  

(4)

where:

- \(f_c\) - represents the conversion factor;
- \(\rho_u\) - represents the AVM of wood at a \(u\) moisture content;

**Research Results**

The following tables (Table 2 and Table 3) present the AVM of spruce wood for pulp, calculated for different moisture content values, as well as the conversion factors necessary for the conversions of mass to volume and the other way round. The first value represents the DVM according to which the other values of the AVM have been determined.

**Table 2. The apparent volumic mass of pulpwood**

<table>
<thead>
<tr>
<th>Forest District</th>
<th>Absolute moisture content (%)</th>
<th>Relative moisture content (%)</th>
<th>Apparent volumic mass (kg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>10</td>
<td>17</td>
</tr>
<tr>
<td>Miercurea</td>
<td>369</td>
<td>405</td>
<td>442</td>
</tr>
<tr>
<td>Sibiului</td>
<td>327</td>
<td>360</td>
<td>393</td>
</tr>
<tr>
<td>Teliu</td>
<td>418</td>
<td>460</td>
<td>501</td>
</tr>
<tr>
<td>Măneciu</td>
<td>308</td>
<td>339</td>
<td>369</td>
</tr>
<tr>
<td>Vidraru</td>
<td>308</td>
<td>339</td>
<td>369</td>
</tr>
<tr>
<td>Average values</td>
<td>356</td>
<td>391</td>
<td>426</td>
</tr>
</tbody>
</table>

**Table 3. Conversion factors for the conversion of tones to cubic meters of wood**

<table>
<thead>
<tr>
<th>Forest District</th>
<th>Absolute moisture content (%)</th>
<th>Relative moisture content (%)</th>
<th>Conversion factors for the conversion of tones to cubic meters of wood</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>10</td>
<td>17</td>
</tr>
<tr>
<td>Miercurea</td>
<td>2.71</td>
<td>2.47</td>
<td>2.26</td>
</tr>
<tr>
<td>Sibiului</td>
<td>3.06</td>
<td>2.78</td>
<td>2.54</td>
</tr>
<tr>
<td>Teliu</td>
<td>2.39</td>
<td>2.17</td>
<td>2.00</td>
</tr>
<tr>
<td>Măneciu</td>
<td>3.25</td>
<td>2.95</td>
<td>2.71</td>
</tr>
<tr>
<td>Vidraru</td>
<td>2.81</td>
<td>2.56</td>
<td>2.35</td>
</tr>
</tbody>
</table>
The AVM depends on many factors. Same authors (Gräns et al. 2009) claim that wood density is strongly controlled genetically; others (Leahu, 1994; Giurgiu et al., 2004) have shown that the most important factors which influence wood density are age and site conditions expressed by site quality. These statements are mostly confirmed by the results obtained during this research. Thus, one notices in the case of spruce pulpwood that the AVM is bigger in the case of sites of inferior quality as opposed to sites of average quality. Consequently, research locations Teliu and Maneclu, both of an average site quality, have the smallest values of AVM. Also, the volumic mass is bigger in the case of an older age, 110 years at Miercurea Sibiului Forest District as opposed to 30-35 years at Teliu and Vidraru Forest Districts. The growth of wood AVM with the tree age is mainly determined by the decrease of the average width of the annual ring. The width of the annual ring determines a significant increase of wood AVM as the site quality decreases (Giurgiu et al., 2004). In the case of spruce, wood density decreases with the increase of annual ring width, the main cause being the decrease of the proportion of late wood and of the proportion of tracheids with thick walls, while the proportion of early wood and that of tracheids with thin walls increases. Generally speaking late wood is more dense than early wood, the AVM being up to 1,5...3 times bigger (Beldeanu, 2001). Raiskila et al. (2006) have shown that mean annual ring density was 0.461 g/cm$^3$, the latewood density was 0.750 g/cm$^3$ and the early wood density was 0.415 g/cm$^3$. Decoux et al. (2004) have shown that wood density exhibits maximum variability at the intra-ring scale, ranging from about 300 to 1000 kg/m$^3$. Wood density is relatively independent of the growth rate and climatic conditions during the first part of the growing season, but increased with decreasing radial growth rate later in the growing season (Bouriaud et al., 2005). The volumic mass of wood with bark depends on the proportion of bark in the transversal section of wood. Bark density is 5-10% higher than wood density on base and decreasing to the top (Dibdiakova and Vadla, 2012).

Moisture content represents an extremely important characteristic of wood with a significant influence on the physical and mechanical properties of wood. Here, moisture content is one of the factors which determine the AVM of wood. All forest measurement tables which refer to the AVM of wood, to its weight and to the conversion factors for the conversion of tones to cubic meters consider moisture content the main factor. In the case of freshly fallen spruce wood, research has revealed an absolute moisture content of 151% at Vidraru. That is why, in the tables above, the values of the AVM and of the corresponding conversion factors have been calculated up to an absolute moisture content of 150%. In the case of the other research locations, the moisture content was 37% after three months of storage at Miercurea Sibiului, 65% after one month of storage at Maneclu and 71% after one month of storage at Teliu. Another important factor which influences the moisture content of freshly fallen wood is the species or the group of species. Resinous species have a moisture content between 100 and 150%, with spruce having a maximum moisture content of approximately 212% (Beldeanu, 2001).

Research in the field acknowledges the correlation between the AVM and the moisture content as being a linear one which can be expressed with the help of the following equation (Decei and Anca, 1968):

\[ y = a + bx \] (5)

where:

- $y$ - represents the apparent density
- $x$ - represents absolute wood moisture content
- $a$, $b$ - represent the coefficients of the regression equation

Thus, based on the values of the AVM, models of the regression equations which describe the dependency of AVM on wood moisture content for each research location are presented below (fig. 4).

![Regression equations of AVM for the studied populations](image)

The simple correlation coefficient $r > 0,999$ for all models indicates a strong linear relationship between AVM and absolute wood moisture content. The coefficient of determination $R^2$ is also above 0,999 and shows that the
Variation of AVM is determined by the absolute wood moisture content. In order to reject the null hypothesis, the significance of regression equations was tested using Fisher statistical test. For all models $F_{\text{experimental}}$ is greater than $F_{\text{theoretical}}$ at 1 and 14 degrees of freedom and at 0.1% level of significance. Therefore, the null hypothesis is not valid, regressions were significant overall. The results of simple linear regression analysis of AVM in relation to absolute wood moisture content are presented in Table 4.

### Table 4. Results of simple linear regression analysis of AVM in relation to absolute moisture content

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Standard Error</th>
<th>$t$ Statistic</th>
<th>P - value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Miercurea Sibiului</strong> ($R^2 &gt; 0.999$; Standard Error 0.329; Degrees of freedom Regression 1, Residual 14; Significance $F &lt; 0.001^{***}$)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>368.6</td>
<td>0.1572</td>
<td>2343.28</td>
<td>$&lt; 0.001^{***}$</td>
</tr>
<tr>
<td>Absolute Moisture</td>
<td>3.684</td>
<td>0.0017</td>
<td>2062.33</td>
<td>$&lt; 0.001^{***}$</td>
</tr>
<tr>
<td><strong>Teliu</strong> ($R^2 &gt; 0.999$; Standard Error 0.363; Degrees of freedom Regression 1, Residual 14; Significance $F &lt; 0.001^{***}$)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>327.0</td>
<td>0.1734</td>
<td>1885.234</td>
<td>$&lt; 0.001^{***}$</td>
</tr>
<tr>
<td>Absolute Moisture</td>
<td>3.263</td>
<td>0.0019</td>
<td>1655.992</td>
<td>$&lt; 0.001^{***}$</td>
</tr>
<tr>
<td><strong>Măneciu</strong> ($R^2 &gt; 0.999$; Standard Error 0.301; Degrees of freedom Regression 1, Residual 14; Significance $F &lt; 0.001^{***}$)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>417.8</td>
<td>0.1439</td>
<td>2903.504</td>
<td>$&lt; 0.001^{***}$</td>
</tr>
<tr>
<td>Absolute Moisture</td>
<td>4.172</td>
<td>0.0016</td>
<td>2552.565</td>
<td>$&lt; 0.001^{***}$</td>
</tr>
<tr>
<td><strong>Vidraru</strong> ($R^2 &gt; 0.999$; Standard Error 0.320; Degrees of freedom Regression 1, Residual 14; Significance $F &lt; 0.001^{***}$)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>307.8</td>
<td>0.1529</td>
<td>2012.619</td>
<td>$&lt; 0.001^{***}$</td>
</tr>
<tr>
<td>Absolute Moisture</td>
<td>3.074</td>
<td>0.0017</td>
<td>1769.844</td>
<td>$&lt; 0.001^{***}$</td>
</tr>
</tbody>
</table>

Note: Asterisks denote significant correlations, $*** p < 0.001$

The use of such regression equations makes the determination of AVM much easier in practical silviculture because in this way only determinations of wood moisture content are necessary.

An analysis of the results obtained with respect to AVM following the use of the above mentioned research methodology, emphasizes the fact that DVM and AVM vary in the case of the same species depending on the research location. The variation coefficients (population and inter-population) of spruce pulpwood are presented in Table 5.

### Table 5. The variation coefficients of spruce wood apparent volumic mass

<table>
<thead>
<tr>
<th>Forest District</th>
<th>Population variation coefficient ($s%$)</th>
<th>Inter-population variation coefficient ($s%$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Miercurea Sibiului</td>
<td>8.6</td>
<td>13.7</td>
</tr>
<tr>
<td>Teliu</td>
<td>7.6</td>
<td></td>
</tr>
<tr>
<td>Măneciu</td>
<td>9.2</td>
<td></td>
</tr>
<tr>
<td>Vidraru</td>
<td>5.1</td>
<td></td>
</tr>
</tbody>
</table>

$s\%$ represents the variation coefficient of apparent volumic mass at population level, $s_{si}\%$ represents the variation coefficient of apparent volumic mass at inter-population level.

Usually, at population level, the values of variation coefficients of pulpwood DVM are situated below the value of 10% mentioned by the research in the field as being the variation coefficient of wood density (Giurgiu, 1972). Considering the difference between research locations and the average value of wood volumic mass, expressed in kg/m$^3$, as well as the impact that this difference might have on accuracy when big quantities of wood are measured, the use of local values is recommended. The tree age and their response to different site conditions make the inter-population variation coefficient be of 13.7%. Likewise, wood pieces from which slices for analysis have been extracted came from different heights. Duchesne et al. (1997) found different wood and pulp properties for butt, middle, and top logs. Also, dominant trees had different properties than intermediate and suppressed ones. Dominant trees had lower basic density (Molteberg and Høibø, 2007). For spruce, Repola (2006), found that the vertical dependence of basic density was slight, density first decreased slowly and then started to increase when approaching the top. Basic density first decreased to a minimum at a height of 5 m and then increased towards the top ((Molteberg and Høibø, 2007).

### Conclusions

The results obtained show that the DVM and implicitly the AVM of spruce logs vary with the tree age and the vegetation conditions expressed by the site quality. In the case of the populations studied, the spruce pulpwood DVM varied between 308 and 418 kg/m$^3$, the average being of 356 kg/m$^3$. The methodology used here allowed the determination of the conversion factors necessary for the conversions from mass to volume. Also, it allowed the establishment of certain regression equations for the determination of the AVM where the only independent variable is the absolute wood moisture content. By determining the variation coefficients of volumic mass at both population and
inter-population level, the importance of establishing representative batches for the wood under research, on the one hand, and the importance of using local values over average values, on the other hand, have been emphasized.

References


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Model Investigations of Groundwater Pollution by Nitrogen Compounds

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Abstract

The pollution of ground water is an indicator of the environmental pollution and is especially susceptible to the impact of anthropogenic factors. Agriculture is general source of water pollution. The aim of the research is investigation of movement of pollution with groundwater when object of pollution is concentrated organic waste. To determine the dynamics of contaminants, twenty-one 3-metre deep piezometers were installed near the source of pollution. The level of pollution of groundwater differs from year to year, nevertheless when a concentrated source of pollution is present, it remains high. Diffusion of nitrogen combinations in groundwater depends on relief of the soil surface; the concentration of water contaminants is greater in lower areas. In early spring the process of nitrification is intensive, after 6 weeks the process of nitrification slows down and the process of denitrification intensifies.

Key words: groundwater, piezometers, nitrates, nitrites, contaminants

Introduction

In recent years, due to the intensity of agricultural activity, pollution of groundwater with agricultural contaminants has been great (Anderson, 1993; Iqbal, 2000; Mitchell et al., 2003) and constantly increasing (Fedkiw, 1991; Datta et al, 1999; Rutkoviene et al., 2001). Degradation of ground and surface waters is becoming more intense due to agricultural activity because: uncultivated lands are being cultivated in agricultural purposes, agriculture causes erosion and destruction of soil structure; due to fertilizers and pesticides applied chemical pollution is huge as well as pollution from cattle-rearing complexes.

In Pensilvania, pollution of groundwater with nitrates within different categories of land usage: forest, agriculture, living localities, land for industrial and commercial purpose was compared. It was found that concentration of pollution with nitrates is much greater in agricultural and industrial areas (Senior, 1996). One of the reasons of pollution of groundwater with nitrates is surplus of nitrates, when organic fertilizers are applied without considering real needs of plants and soil (Muchovej, Rechcigl, 1995; Lord, Mitchell, 1998; Stone et al., 1998). Nitrates are very soluble and mobile and therefore are leaching away easily out of soil, however, plants assume them out of soil very easily as well (Hallberg, 1989; Clawges, Vowinkel, 1996). Nitrates pollute ground and surface water and consequently the problem of eutrophication arises (Groeneveld et al., 2001).

Dutch scientists have researched the balance of anthropogenic nitrogen and determined that the biggest part (67%) of nitrogen is lost due to agricultural activity, 15% of total nitrogenic emission is washed away and pollutes groundwater with nitrates, causing eutrophication in surface water (Olsthoorn, Fong, 1998). Pollution with nitrates in different regions varies, nevertheless in suburban areas and regions of intensive agricultural activity it is higher than anywhere else. Groundwater moves slowly in grounds of moderate heaviness – approximately 1 cm per day (Datta et al., 1999). In locations where directions of groundwater and surface water do not coincide, movement of water through the ground and time in which nutritious matters are washed away becomes unpredictable and can be delayed to up to 30 years. Even when intensive agricultural activity ceases the areas affected should not expect amelioration in groundwater quality (Wailand et al., 2000). Designing different situations Australian scientists determined that after eliminating objects of pollution the quality of groundwater would become acceptable in 15 to 20 years (Baber et al., 1996). In Lithuania groundwater in an area where once a farmstead was situated remained polluted after 15 years, while groundwater in a nearby pasture was clean (Šileika et al., 1998).

It has been known for 20 years that to improve the quality of groundwater we need to control the process of leaching away of nitrates from soil (Madison, Brunei, 1985). It is very complicated because knowledge on balance of nitrogen matters as well as nitrogen dynamics in ecosystems is necessary (Huwe, Totshe, 1995). Analyses of reference materials show that much research on groundwater pollution with nitrogen compounds has been carried out. However, still missing is model field research on diffusion and migration of nitrogen compounds.

The aim of the research is investigation of movement of pollution with groundwater when object of pollution is concentrated organic waste.

Materials and Methods

To determine the dynamics of contaminants, twenty-one 3-metre deep piezometers were installed near the source of pollution. Figure 1 shows the scheme of installed piezometers. Piezometers were installed in a distance of 20-50 meters from the source of pollution. The source of pollution has been chosen as typical to a countryside area - in spring (March 2010, April 2011) a huge pile of manure (d=2 m) was made. Granulometric composition was determined in typical sites, SE, State Land Exploitation Institute, according to FAO/ISRIC, taking ground samples from different layers. In the upper layer of the ground loamy soil of moderate heaviness (p1) prevails. Its filtration coefficient is 0.07 m/d. In the second ground layer heavy loamy soil (p2) prevails with a filtration coefficient of 0.05 m/d.
Groundwater samples from piezometer as well as measurements of water level with regard to the soil surface are taken every two weeks in the period of April-September 2010-2011 (until level of groundwater has become less than 3 meters from the soil surface).

Examination of chemical analytes was carried out at Environmental laboratory in Lithuanian University of Agriculture. The following analytes such as nitrates – potentiometric LST ISO 7890-2.1998, nitrites - colorimetric LAND 39-2000, ammonium ions colorimetric LAND 38-2000 and permanganate value (P.V.) – oxidation, pH and Rh (redox potential) potentiometric were determined.

All the maps were created and surfaces generated using standard functionality of ArcGIS software. Standard Local Polynomial Interpolation was used to get the prediction map of land surface elevation and the map of ground water depth. The last surface was contoured to get better visual representation of two rasters on the same map. Concentrations of various chemical components are represented as bar charts, each column corresponding a separate observation date, ranging from the most left, corresponding to the beginning of observations in April or March (depending on the year) till the far right, identifying the end of observations (September).

In order to check the significance of determined alternation differences of annual water quality indicators, the Student t-criteria were used. If \( p > 0, 05 \) – the difference is significant. The program “STATISTICA” was used for determining correlation coefficients. The correlation link was evaluated according to Pearson correlation coefficient. The significance level \( (p > 0, 05) \) of 0, 05 were chosen for verification of statistical hypotheses.

### Results and Discussion

The level of pollution of groundwater with nitrates is high. In 2011 the concentration of nitrates in the water of piezometers was greater than in 2010 \( (p= 0.01) \). Figure 2 shows the dynamics and diffusion of nitrate concentration in the water of piezometers. The highest pollution with nitrates in 2010 in section A was detected in water of piezometer 3-2 (average value 1451.65 mg \( 1^l \)). The maximum nitrate concentration was noted on May 15 (2500 mg \( 1^l \)) and starting from the middle of June it began to decrease until in September it arrived at its minimum value of 950 mg \( 1^l \). High pollution was also measured in piezometers 0 (187.5 mg \( 1^l \)) and 4-2 (135.2 mg \( 1^l \)). In the rest of piezometers the pollution was low, values changing between 1, 45 and 11,45 mg \( 1^l \). In section B the highest pollution determined was in the water of piezometer 4-1 (106.15 mg \( 1^l \)). The maximum value of nitrates was noted on June 9 (400 mg \( 1^l \)) and after that went into decrease. In other piezometers the average concentration of nitrates was low values changing from 1 to 6.75 mg \( 1^l \). Having calculated coefficients of correlation between the height of soil surface and average concentration of nitrates, no significant correlation in 2010 was found either in section A or section B.

In 2011 the concentration of nitrates in the water of piezometers was higher than in 2010. In section A the highest concentration of nitrates was detected in water of piezometer 1-2 (2014 mg \( 1^l \)). The maximum concentration of nitrates was noted on July 14 ((5500 mg \( 1^l \)) from then on it began to decrease until September (minimum value 250 mg \( 1^l \)). In piezometers 4-2 (1945 mg \( 1^l \)), 4-1 (1447 mg \( 1^l \)) and 3-2 (1310 mg \( 1^l \)) maximum nitrate concentration on July 14 was 5200, 4900 and 3350 mg \( 1^l \) respectively. High average concentration of nitrates was measured in piezometers 0 (673 mg \( 1^l \)), 2-4 (192 mg \( 1^l \)) and 1-4 (174 mg \( 1^l \)). The lowest concentration of nitrates was detected in piezometers 3-4 (8 mg \( 1^l \)) and 5-4 (10 mg \( 1^l \)). In section B the highest concentration of nitrates was detected in the water of piezometer 2-1 (758 mg \( 1^l \)), 1-1 (702 mg \( 1^l \)), 0 (673 mg \( 1^l \)), 4-1 (633 mg \( 1^l \)), 2-3 (615 mg \( 1^l \)) and 5-3 (613 mg \( 1^l \)). The lowest concentration of nitrates was detected in piezometers 5-1 (9 mg \( 1^l \)) and in other piezometers concentration of nitrates changed between 81 and 135 mg \( 1^l \). Having calculated coefficients of correlation between the height of soil
surface and average concentration of nitrates in 2011, in section A it was found that the concentration of nitrates is lower in the areas with higher soil surface. (a strong negative correlation was found r = -0.689, p = 0.021). In section B no significant correlation was found.

The concentration of ammonium ions in the water of piezometers was higher in 2010 than in 2011 (p=0.000). Diffusion and dynamics is shown in Figure 3. In 2010 in section A the highest average concentration of ammonium ions was found in the water of piezometer 3-2 (3.68 mg l⁻¹), maximum concentration of ammonium ions was detected on September 1 (6.8 mg l⁻¹). High pollution was found also in piezometers 5-4 (average NH₄⁺ vertė – 2.96 mg l⁻¹), maximum concentration of ammonium ions was found on May 23 (9.7 mg l⁻¹), in the water of piezometers 5-2 and 4-2 maximum concentrations on May 21 (4.2 mg l⁻¹) and June 23 (7.6 mg l⁻¹) respectively. In other piezometers the average value of ions concentration varied between 0.9 and 2.61 mg l⁻¹. In section B the highest pollution with ammonium ions was found in the water of piezometer 0 (2.6 mg l⁻¹), the maximum concentration of ammonium ions was found on June 23 (3.5 mg l⁻¹). In other piezometers the average value of concentration of ammonium ions varied from 0.79 to 2.3 mg l⁻¹. In the end of summer the concentration of ammonium ions increases. Having calculated coefficients of correlation between the height of the soil surface and average concentration of ammonium, in 2010 in section A the ammonium concentration is lower in areas where the soil surface is higher (strong negative correlation r = -0.613, p = 0.0240). In section B no statistically significant correlation was found.

In 2010 in section A the highest average concentration of ammonium was found in the water of piezometer 3-2 (4.87 mg l⁻¹), maximum concentration of ammon was found on August 4 (6.3 mg l⁻¹). In other piezometers the average value of concentration of ammonium ions in water varied between 0.89 and 2.53 mg l⁻¹. In section B the highest pollution with ammonium ions was found in the water of piezometer 4-1 (3.24 mg l⁻¹) arriving at the maximum value of concentration of ammonium ions on September 1 (4.45 mg l⁻¹). In other piezometers the average concentration of ammonium ions varied from 0.87 to 2.62 mg l⁻¹. The concentration of ammonium ions increases in the end of summer. Having calculated coefficients of correlation between the height of the earth surface and average concentration of ammonium ions, both in 2010 in sections A and B the concentration of ammonium ions is lower in areas where the soil surface is higher (strong negative correlation r = -0.577, p = 0.045; r = -0.688, p = 0.045).

In 2011 concentration of nitrates in the water of piezometers was greater than in 2010 (p= 0.009) Figure 4 shows dynamics and diffusion of concentration of nitrates in the water of piezometers in years 2010 and 2011. In 2010 the greatest concentration of nitrates was detected in the water of piezometer 0 (0.16 mg l⁻¹), with maximum value arriving at 0.78 mg l⁻¹ on June 23. In the water of piezometer 5-4 average value of concentration of nitrates found was 0.13 mg l⁻¹, maximum value of concentration of ammonium ions was detected on June 23 (2.09 mg l⁻¹), in the water of piezometers 4-2 and 3-2 (average values 0.09 and 0.10 mg l⁻¹), maximum concentration detected on June 23 0.26 mg l⁻¹ ir 0.37 mg l⁻¹ respectively. In the water of other piezometers an average value of concentration of nitrates varied from 0.01 to 0.04 mg l⁻¹. In section B, as well as in section A the greatest concentration of nitrates was detected in the water of piezometer 0 (0.16 mg l⁻¹). In other piezometers an average value of concentration varied from 0.01 to 0.07 mg l⁻¹. Maximum values in most piezometers were detected on June 23. Having calculated coefficients of correlation between the height of the soil surface and average concentration of ammonium ions, both in 2011 in sections A and B the concentration of ammonium ions is lower in areas where the soil surface is higher (strong negative correlation r = -0.577, p = 0.045; r = -0.688, p = 0.045).

In 2011 in section A the greatest average concentration of nitrates was detected in the water of piezometer 4-2 (0.34 mg l⁻¹), maximum concentration of nitrates was detected on April 16 (2.49 mg l⁻¹). In other piezometers an average value of concentration of nitrates varied from 0.09 to 0.27 mg l⁻¹. In section B the greatest average value of concentration of nitrates was found in the water of piezometer 3-1 (0.31 mg l⁻¹), maximum concentration of nitrates was detected on April 16 (1.7 mg l⁻¹). In other piezometers an average concentration of nitrates varied from 0.08 to 0.2 mg l⁻¹. Having calculated the coefficients of correlation between the height of the soil surface and average concentration of nitrates in 2011 it was found that in section A concentration of nitrates is lower where the height of soil surface in bigger (strong negative correlation r = -0.776, p = 0.005). Correlation in section B was found statistically insignificant.

In 2011 the permanganate value in the water of piezometers was higher than in 2010 (p= 0.0009). The dynamics and diffusion of value of permanganate value in the water of piezometers is shown in Figure 5.

In 2010 in section A the greatest average value of permanganate value was detected in the water of piezometer 3-2 (52.45 mg l⁻¹ O₂), maximum value was detected on August 4, August 18 and September 1 (77 mg l⁻¹ O₂). In the remaining piezometers an average value of permanganate index in water varied from 13.36 to 24.8 mg l⁻¹ O₂. As in case of the value of concentration of ammonium ions, the value of permanganate value increases in the end of summer. In section B the greatest permanganate value was detected in the water of piezometer 0 (24.06 mg l⁻¹ O₂), with maximum value arriving at 68.8 mg l⁻¹ O₂ on June 23. Having calculated correlation coeficients between the height of the soil surface and the average value of permanganate value in 2010 no statistically significant correlation was found either in section A or B.
Figure 2. Nitrate concentration in water of piezometers (2010-2011)

Figure 3. Ammonium ions concentration in the water of piezometers in 2010 and 2011

Figure 4. Nitrite concentration in the water of piezometers in 2010 and 2011
In 2011 in section A the greatest average of permanganate value was detected in the water of piezometer 3-2 (58.93 mg l$^{-1}$), maximum value was detected on August 4, August 18 and September 1 (77 mg l$^{-1}$O$_2$). In the remaining piezometers an average of permanganate value in water varied from 23.94 to 42.27 mg l$^{-1}$O$_2$. As in case of the value of concentration of ammonium ions, permanganate value increases in the end of summer. In section B the greatest permanganate value was detected in the water of piezometer 0 (38.62 mg l$^{-1}$O$_2$), with maximum value detected on May 15 (61.6 mg l$^{-1}$O$_2$). In other piezometers the permanganate value varied between 22.32 - 36.36 mg l$^{-1}$O$_2$. Having calculated correlation coefficients between the height of soil surface and the average of permanganate value in 2010 no statistically significant correlation was found either in section A or B.

Pollution in all the parameters of quality was higher in 2011 than in 2010. In 2011 during the seven months of research there was more precipitation than in 2003 (2003 – 342.8 mm/7month, 2010 - 342.8 mm/7month), air temperature was of the research period was higher in 2010 (2010 -15°C, 2011 - 11.62 °C). In 2011 the filtration of precipitation into groundwater was more intensive due to a greater amount of precipitation and lower temperature and therefore the concentration of contamination was significantly greater that year.

Migration and transformation of nitrogen in model systems are shown in figure 6. In the picture the changing values of water samples in 21 piezometers (Figure 1 3-2 piezometres) and water level from soil surface in 2010 are shown. Pollution levels in a selected piezometer are high in all parameters and all year round. Figure 6 displays the change in the water sample of 1 out of 21 piezometers (3-2) and the water level from the land surface. Other piezometers yielded similar results.

According to the data provided by Kaunas meteorology-station, the soil heated on 2010 April 11, when the groundwater stratified 1, 07 m from the land surface. According to the determined soil texture the loam of average heaviness dominates at the upper layer of the ground ($p_1$) – filtration coefficient is 0, 05 – 0, 1 m/p; at the second layer of the ground the loam of average heaviness dominates - filtration coefficient is 0, 05 m/p. Because the ground with filtration coefficient varies between 0, 05 to 0, 1 /p dominate, the infiltration of the pollutants together with the precipitation through unsaturated zone to saturated zone will occur in 1, 5 days. The increase in concentration of nitrates and organic substances was recorded on May 12, after 31 days from the ground heat. Pollutants from the pollution source to the piezometer moved at speed 0, 67 m/p. Pollutants move with the groundwater, also the reactions of nitrogen compound changes occur. The water is polluted by the nitrates: the maximum concentration after 45 days is 250 mg l$^{-1}$. After that the concentration of nitrates decreased and that of ammonium ions increased reaching the maximum of 7 mg l$^{-1}$ at the end of the research, i.e. after 142 days. The water is polluted by organic substances reaching the maximal concentration of 78 mg l$^{-1}$O$_2$ after 122 days. The concentration of nitrites was not high, the highest was in summer reaching 0.4 mg l$^{-1}$. The determined rH value is lower than 28 which mean that the environment is reductive. At the spring, the rH value is higher and close to the neutral, later it decreases. At the same time the concentration of nitrites decreases too.

Inter-correlation coefficients of the quality parameter indicators were calculated. the strong positive correlation was determined between organic substance and the nitrate concentration ($r=0.4357; p=0.048$), the nitrite concentration ($r=0.6243; p=0.002$), the ammonium ions concentration ($r=0.8453; p=0.000$), between nitrite concentration and the ammonium ions concentration ($r=0.7822; p=0.000$), between the water level and the ammonium ions concentration ($r=0.9153; p=0.000$), the nitrite concentrations ($r=0.8147; p=0.000$) and the quantity of organic substances; between the rH and pH values ($r=0.6071; p=0.004$).
Figure 6. Concentration of nitrates, ammonium ions, redox potential, organic substances and nitrites, water level from land surface piezometer 3-2 in water (2010)

Conclusions

The level of pollution of groundwater differs from year to year, nevertheless when a concentrated source of pollution is present, it remains high. In 2011 because of a more abundant quantity of precipitation pollution of groundwater is greater than in 2010.

Diffusion of nitrogen combinations in groundwater depends on relief of the soil surface; the concentration of water contaminants is greater in lower areas. The strongest negative correlation ($r = -0.688$, $p = 0.045$) has been detected between concentration of ammonium ions and level of the soil surface.

The speed of contaminant movement is 0.67 m/d. In early spring with low concentration of ammonium ions pH is close to neutral (7.2-7.55), the process of nitrification is intensive. After 6 weeks because of great concentration of ammonium ions the process of nitrification slows down, the environment becomes reductive ($r$H value is less than 28), the process of denitrification intensifies.

Model research of concentrated pollution of groundwater concedes information on migration of contaminants and allows scientists to provide the means for lessening the pollution of groundwater.

References


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Evaluation of the Natural Value of Land Before and after Planning Procedures

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Abstract

Socioeconomic development involves expansion of urban areas, which has its consequence in changes in the condition of the environment. Mismanagement of the process results in disturbing the environmental balance. Examples of this effect include intensive, frequently wasteful exploitation of non-renewable natural resources and overly rapid consumption or improper management of renewable resources. Chaotically located investments result in pollution of the soil as well as surface and underground waters.

The aim of this paper is to value the natural features of an area before the local land use plan is approved and the same are in the condition described by the plan. A comparison of the value before and after the plan is drawn up shows whether the intended project has met the conditions of natural compensation. They are met when the land use is planned in such a way so as to allow it to retain its value after the area has been transformed. The method used for the analysis is called 1st generation analysis of landscape value. It involves adding up the products of multiplication of partial areas with specific land use and the corresponding score point indexes. The index values lie between 0 and 1. The analysis was started with the stock-taking of the land features and the analysis of cartographic materials, as well as the provisions of the local plan approved in 2004. The state of land development as of 1995 and the specified target state, as per the plan, provided grounds for determination of the intensity of the environmental change resulting from the land development policy implemented in the area.

Key words: space; natural value; methods of evaluation, land use planning.

Introduction

A simplified method of valuation of geocomplexes can be applied by following the principle of landscape compensation, taken from the planning system in Germany (NatSchAVO, 1995, SMUL, 2009). The land planning system in Germany includes a scale for valuation of terrain based on its cover. It determines the quality of an area according to its natural value and defines the differences or proportions between the value of the areas. The scale of environmental coefficients (tab. 1) can be a useful method in simplified valuation made for the purpose of land development at the design stage, while observing the principle of not decreasing its natural value (Dworniczak, 2011, Borkowski, 2004, Sporek, 2001). The method can be a reason for optimising the location of a burdensome user by determination of the smallest possible loss in the natural environment for alternative locations and forms of use of adjacent areas.

This method can be used to determine the initial natural value of an area, using the system of score points shown in Table 1. After developing a new plan, the natural value in its new form is calculated. According to the primary assumptions of the method, the natural value of the land development as planned cannot be lower than the initial value (Vosskuhle, 1999, Ciebrat, 2002, Cieślak, 2012).

<table>
<thead>
<tr>
<th>Category of land</th>
<th>Land use</th>
<th>Coefficient (pts/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A0</td>
<td>built-up area, impervious to water (roads, buildings, paved areas)</td>
<td>0.0</td>
</tr>
<tr>
<td>A1</td>
<td>permeable surfaces, areas of greenery around buildings</td>
<td>0.1</td>
</tr>
<tr>
<td>A2</td>
<td>areas of greenery in residential quarters, allotments, orchards, greens</td>
<td>0.2</td>
</tr>
<tr>
<td>A3</td>
<td>intensively cultivated agricultural land (arable land)</td>
<td>0.3</td>
</tr>
<tr>
<td>A4</td>
<td>other intensively used areas: orchard plantations, grassland</td>
<td>0.4</td>
</tr>
<tr>
<td>A5</td>
<td>water bodies with poor natural structure (regulated rivers, fish breeding ponds)</td>
<td>0.5</td>
</tr>
<tr>
<td>A6</td>
<td>forests with tree species foreign to the local landscape (forest plantations, areas afforested with foreign tree species)</td>
<td>0.6</td>
</tr>
<tr>
<td>A7</td>
<td>meadows, forest glades, areas used extensively or overgrown with wild vegetation</td>
<td>0.7</td>
</tr>
<tr>
<td>A8</td>
<td>natural forests, parks, avenues, greens with old trees, individual old trees, afforestation in floodland</td>
<td>0.8</td>
</tr>
<tr>
<td>A9</td>
<td>water bodies with rich natural structure</td>
<td>0.9</td>
</tr>
<tr>
<td>A10</td>
<td>biotope as understood by the natural environment regulations (national parks, reserves)</td>
<td>1.0</td>
</tr>
</tbody>
</table>


In order to calculate an initial value for an area under transformation, the size of the area must be multiplied by the coefficient which corresponds to the current land use. The resultant total product is the natural value of the area estimated from its cover. Likewise, such a value can be determined for the forms of land use provided for in the plan.
Comparison of the valuation results in both cases provides information about the change in the environment quality resulting from the planned changes of the land use.

**Transformation of the natural environment**

The aim of the land use planning is to distribute, in a manner which is coordinated and harmonised with the natural environment, the results of human activities aimed at satisfying the needs of the population inhabiting an area (Dubel, 1998). Such an approach to land planning necessitates observing the principles of sustainable development for the protection of the environment. In general terms, the socioeconomic development can be described as a set of interdependent systems which comprise:

- the needs of the society;
- the economy ↔ technology;
- environmental resources (Zieńko, Tokarski, 1999).

However, socioeconomic development is not possible without certain loss to the quality of the natural environment. Such loss results from expanding built-up areas, development of infrastructure, mining, etc. It is the role of land use planning to minimise such loss. Changes in the environment are monitored by means of environmental impact assessments for investment projects and broad ecophysiographic assessments (Gibson, 1979, Boyd, Wainger, 2003). The relationships between the society, the economy and the natural environment are presented in the figure 1.

![Diagram of Relationships: society ↔ economy → natural environment](image)

The research part of the paper presents a study of changes in the natural value of the landscape in areas where land management is conducted without a procedure for approving local plans and in areas for which such plans are approved. The aim of the study was to identify the level of environmental change for the areas with the lowest level of planning culture and for those areas where such a level is the highest.

**Determination of changes of the natural quality of an area with the use of simplified landscape valuation**

To achieve the objective of the study, which involved determination of the usability of the method to identify environmental changes, it was decided to analyse the environmental changes which could take place after the final implementation of the land use plan approved for the area.

The borders of the selected area are shown in Fig. 2. Stock-taking of the selected area was performed and the area was examined in terms of its natural value. It is situated on the outskirts of a town, which has been rapidly developing for the past fifteen years. The area is delimited by the roads and the river and by the administrative borders of the town. A land use plan was developed for the part of the town of Ostrołęka – the Bemowo district – which includes the analysed area (Resolution No. 296/XXVII/2004 ... 2004).

In the next stage of the study, a stock-taking of the area was performed. The results were used to calculate the size of each natural unit. The topographic map drawn up in 1995 was used and the initial natural value of the area was determined as of this date.

Categories of land cover were assigned to specified unit areas as shown in Table 1. The areas of the units were multiplied by the corresponding coefficients. The resulting values for the unit areas were summed up, which produced
the value for the landscape of the analysed area before the local land use plan was implemented, and, more specifically, the natural value as of 1995. The specific contribution of each area and their natural value as well as the ultimate value of the area is shown in Table 2.

Table 2. The physiographic value of the area before the land use plan for part of the town of Ostrołęka – the Bemowo district was implemented

<table>
<thead>
<tr>
<th>Category of the area</th>
<th>Natural coefficient</th>
<th>Area, ha</th>
<th>Natural value</th>
</tr>
</thead>
<tbody>
<tr>
<td>A0</td>
<td>0.0</td>
<td>8.62</td>
<td>0.00</td>
</tr>
<tr>
<td>A1</td>
<td>0.1</td>
<td>15.94</td>
<td>1.59</td>
</tr>
<tr>
<td>A2</td>
<td>0.2</td>
<td>6.35</td>
<td>1.27</td>
</tr>
<tr>
<td>A3</td>
<td>0.3</td>
<td>2.20</td>
<td>0.66</td>
</tr>
<tr>
<td>A4</td>
<td>0.4</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>A5</td>
<td>0.5</td>
<td>0.02</td>
<td>0.01</td>
</tr>
<tr>
<td>A6</td>
<td>0.6</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>A7</td>
<td>0.7</td>
<td>2.65</td>
<td>1.86</td>
</tr>
<tr>
<td>A8</td>
<td>0.8</td>
<td>14.37</td>
<td>11.49</td>
</tr>
<tr>
<td>A9</td>
<td>0.9</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>A10</td>
<td>1.0</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Suma</td>
<td>-</td>
<td>50.14</td>
<td>16.88</td>
</tr>
</tbody>
</table>

Source: prepared by the author
A similar procedure was applied in order to determine the natural value of an area provided the local land use plan is implemented completely. The stock taking covered the same area as earlier, but an analysis of specific provisions of the plan was necessary to determine classes of specific areas. The size of some areas identified in Table 1 could not be determined based on the map alone. This results from the fact that the forms of land use specified in the plan are a future matter, not implemented as of the date of the analysis, while the study aimed at determination of the ultimate natural value, after the plan has been fully implemented in the area delimited by its borders. In order to determine the final value in the case of single-family residential buildings with potential non-burdensome services and with elements of technical infrastructure and surrounding greenery, marked on the plan as MNU, the text part of the plan was checked for the minimum percentage of the area of the biologically active area of this function, which – according to the plan – is not smaller than 30% of the plot area. This means that 30% of the area should be subtracted from the built-up area, classified as A0 according to Table No 1, assuming that this must be greenery accompanying buildings, therefore the area is classified as A1.

The areas of the landscape units in the design state were multiplied by the corresponding coefficients. This produced the natural values for individual categories of the land within the limits of the analysed area. The total numbers for the areas are the value of the landscape after the local land use plan for the part of the town of Ostrołęka – the Bemowo district – was implemented. The following is a tabular listing of the values for the unit areas and the total natural value for the design state (Table 3).

Table 3. The natural value for the analysed area according to the local land use plan for the part of the town of Ostrołęka – the Bemowo district.

<table>
<thead>
<tr>
<th>Category of the area</th>
<th>Natural coefficient</th>
<th>Area, ha</th>
<th>Natural value</th>
</tr>
</thead>
<tbody>
<tr>
<td>A0</td>
<td>0</td>
<td>26.52</td>
<td>0.00</td>
</tr>
<tr>
<td>A1</td>
<td>0.1</td>
<td>5.24</td>
<td>0.52</td>
</tr>
<tr>
<td>A2</td>
<td>0.2</td>
<td>4.43</td>
<td>0.89</td>
</tr>
<tr>
<td>A3</td>
<td>0.3</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>A4</td>
<td>0.4</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>A5</td>
<td>0.5</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>A6</td>
<td>0.6</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>A7</td>
<td>0.7</td>
<td>0.80</td>
<td>0.56</td>
</tr>
<tr>
<td>A8</td>
<td>0.8</td>
<td>13.15</td>
<td>10.52</td>
</tr>
<tr>
<td>A9</td>
<td>0.9</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>A10</td>
<td>1</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Suma</td>
<td>-</td>
<td>50.14</td>
<td>12.49</td>
</tr>
</tbody>
</table>

Source: prepared by the author

Figure 2. The analysed area, whose stock-taking was performed based on the local plan
Source: prepared by the author
Table 3 shows that the largest area is occupied by land classified as A0, i.e. built-up areas, impervious to water (roads, buildings). The smallest area is that classified as A7, i.e. extensively used area or overgrown with wild vegetation, meadows, forest glades. The analysed area does not include land which could be classified as: A3, A4, A5, A6, A9 or A10. Unfortunately, the higher categories of land account for only 12% of the whole area.

Below (Tab.4) contains two other cases to determine the value nature area. In both cases, the natural area after the land use plan fell. In the first case (Miejscowy plan...2005) - by 42%, in the second [Miejscowy plan..., 2008.] decreased by 20%. In the case described above, it was 27%. This gives an average value of 30%.

Table 4. Comparison of the nature value of other areas before and after the introduction of the plan (1- Jaroty B11; 2 – Skanda)

<table>
<thead>
<tr>
<th>Map of land use in 1995</th>
<th>Map of land use after plan</th>
<th>Natural value in 1995</th>
<th>Natural value after plan</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
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<td>0</td>
<td></td>
</tr>
<tr>
<td>A1</td>
<td>0.02</td>
<td>0.02</td>
<td></td>
</tr>
<tr>
<td>A2</td>
<td>0.11</td>
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<tr>
<td>A3</td>
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<td></td>
</tr>
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<tr>
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</tr>
<tr>
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<td>2.</td>
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<tr>
<td>A10</td>
<td>0.00</td>
<td>0.15</td>
<td></td>
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</tbody>
</table>

Source: prepared by the author

Conclusions

An analysis of the environmental changes resulting from implementation of the local plan in an area was performed with the use of a 1st generation analysis of the landscape value. This is a method developed by German designers which involves valuation of an area based on its cover. The most important assumption of the method is that natural compensation should be achieved. Land use should be planned in such a way that the total natural value after the transformation should be at least equal to such value before the transformation.

It is a goal which is practically unattainable, especially in spatial planning on urban areas. However, owing to this method, such a level of changes can be determined which can be compensated by actions increasing the natural value of the areas, especially those which are not to be built up. Unfortunately, the importance of spatial planning and development in Poland has been neglected despite great benefits to the environment which can be achieved through rational planning.

These claims are supported by the chapter presenting the study results. The results show that the local plans for the areas in question does not comply with the principles of natural compensation. There are areas on the outskirts of towns where the proper principles of land development are not followed. The natural value, determined for the state when the land use plan is totally implemented, was found to be lower than before the transformation. Average percentage of change is 30%. It should be borne in mind that changes in urban land use should result in improvement of the living conditions of the town inhabitants, which is also affected by the quality of the natural environment. Therefore, land use plans must provide for areas with a high natural value, which would compensate for the loss resulting from constructing buildings in the area.

References


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Efficiency of Operating of Kaunas WWTP Digester

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Abstract

Management of waste water sludge is one of the most topical environmental problems that is being gradually solved in Lithuanian waste water treatment plants. Anaerobic sludge digestion is an essential part of sludge treatment. Digestion process not only mineralizes organic pollutants and reduces amount of sludge, but also produces biogas which can be used for energy needs. Different technological and hydraulic factors affect work efficiency of digester. This article analyses the effect of temperature, amount and composition of sludge as well as the process of stirring sludge on gas discharge in Kaunas WWTP digester. It has been determined that degradation degree of organic material affects production of biogas. Sludge digestion process is performed in a narrow temperature interval and for this reason no temperature effect has been observed on the machinery. By stirring sludge effectively a better biogas output can be obtained.

Keywords: digester, sludge, biogas

Introduction

Management and utilization of waste water sludge is a very topical problem at the moment. As more effective and modern technologies of waste water treatment are applied, bigger and bigger amounts of sludge accumulate. The aim of sludge management is to reduce the amount of organic materials while reducing sludge volume at the same time.

Anaerobic sludge digestion is an important part in the chain of sludge management process. During the anaerobic process organic materials in the sludge are mineralized, biogas (a mixture of methane and carbon dioxide) is released in this process, which can be used for energetic and other needs. Anaerobic digestion can be applied to both primary (raw) sludge, which collects in primary sedimentation tanks, and active surplus sludge produced in the process of biological cleansing. Calorific values of gas from digested raw sludge are 10% greater than that from digested surplus sludge (Sludge..., 2006).

Energy production from alternative energy sources including waste water sludge has been gaining popularity in the European Union. The annual growth rate of biogas production is 4.5-5%. Germany and Denmark have already achieved maximum capacities of biogas production form waste water sludge according to the population rates of these countries. Meanwhile waste water treatment plants in Italy, Spain and France produce very little biogas. Regarding the countries that joined the EU later, Slovakia produces the most biogas (91%), followed by Poland (59%), Hungary (34%). Least gas is produced in waste water treatment plants of Czech Republic (26%) and Slovenia (13%) (Bodik et al., 2011).

In Lithuania waste water sludge is digested in waste water treatment plants of Utena, Kaunas, Vilnius, Klaipeda, Siauliai, Panevezys, and Mazeikiai. The total of 13 reactors for anaerobic digestion (methane tanks) is intended to be built in Lithuania. Energetic value of surplus biogas would be 36 thousand MWh a year (Vandentvarka, 2005).

Efficiency of waste water sludge digestion depends on many technological and hydraulic factors. Optimal conditions should be maintained when using methane tanks so that the greatest sludge output was obtained at the lowest expense.

One of the greatest technological factors affecting the work of methane tank is temperature. Anaerobic digestion of sludge can be performed in two temperature modes: mesophilic (20-45°C) and thermophilic (50-65°C). Optimal temperature for sludge digestion depends on the composition of digested sludge, type of metantank, however, it needs to be maintained during many reactions taking place in the reactor to ensure efficient and smooth release of biogas.

Thermophilic digesters are more productive with regard to the duration of sludge stay, sludge load and biogas release, however, they also require bigger amounts of heat, are affected by environmental changes. Anaerobic digesters functioning on mesophilic mode are more widespread because they work at lower temperature scale, require less heat to maintain particular medium and the process is more stable due to bacterial diversity (Monnet, 2003).

Activity of degradation process of anaerobic bacteria in mesophilic methane tanks grows until the optimal temperature of 35-37°C is reached. To heat the sludge up in a metantank extracted methane gas is usually used. External and internal machinery for heating can be used. Expediency of heating equipment is determined by annual average air temperature. In tropical and subtropical regions air temperature is sufficiently high; therefore, no heating machinery needs to be installed in metantank. If air temperature is not sufficient to reach optimal level, to maintain certain temperature artificial heating needs to be installed (Haandel et al., 2007).

To get the greatest possible output of biogas composition of sludge supplied to metantank needs to be controlled. To improve this composition organic waste is sometimes used. For example, in the town of Malma (Sweden) efficiency of methane tank activity at waste water treatment plant was tested. Sludge from household waste with organic waste, sludge from grease traps and fruit and vegetable waste were digested in it. It was determined that digestion of total grease and household waste water sludge increased release of methane. Mixing in some solid household waste water materials increased gas release by 10-15%. Mixing household waste water sludge with different waste possibly improves microorganism activity, speeds up sludge digestion process and increases energy production from methane (Kabouris et al., 2008; Davidsson et al., 2007).

To achieve optimal sludge outcome appropriate stirring of sludge is essential. Stirring ensures that connections between sludge and active biomass are maintained, equal temperature is kept, contents of active biomass is held even,
other biological and physical factors inside the reactor. Different stirring techniques are used worldwide. The most common of them are stirring in a mechanic way and hydraulic without the use the stirrer. A good example of the second way is Dranco method, where sludge is supplied from the top and mixes in the process of going down (Baere, 2006).

There are different types of digesters, however, the most frequently used type is constantly stirred methane tank. The sludge is constantly stirred to prevent the formation of layers (Jorgensen, 2009). In mechanical stirring systems slow speed turbines or stirrers are used (Gerardi, 2003). In both systems the stirring impeller pushes out the sludge and mixes the contents of digester in this way. The most frequent choice of stirrer is one stirrer installed on top. The advantage of stirrers over other ways of stirring is formation of floating layer. A disadvantage worth noticing is the fact that it is difficult to stir the whole content of methane tank this way. There are also risks of mechanical faults and wear and tear of impellers (Metcalf and Eddy, 2003).

Although stirring systems like Dranco, where stirring is performed in a non-mechanical way, are commonly used worldwide, Lithuanian waste water treatment plants only choose mechanical stirrers. In the digesters at Vilnius, Silute, Utena and Panevezys waste water treatment plants mechanical double-blade stirrers are installed. Double-blade stirrers have advantages (over other stirring systems such as external and internal gas stirring, stirring by closed gas systems): better stirring efficiency is achieved as upper blade prevents the layer of foam. On the bottom of the cylindrical part of digester at Utena wastewater plant shields (1.5mX1.5m) are installed which allow not only to stir horizontally, but also to create whirlpools so that stirring is also performed vertically.

Mechanical single blade stirrers are installed in digesters at Kaunas waste water treatment plant. The stirrer produces uninterrupted movement one way. According to the design, shields (similar to those at Utena waste water treatment plant) had to be installed to increase stirring efficiency. Because of absence of shields areas where sludge accumulates and is not stirred appeared on the sides of metantank thus reducing volume of anaerobic digester and affecting its efficiency.

The aim of this study is to assess the effect of temperature, supplied sludge composition and stirring on efficiency of digester activity in Kaunas waste water treatment plant.

The object and methodology of research

To digest sludge Kaunas waste water treatment plant uses two methane tanks with the volume of 8800 m$^3$ each. Two sludge reservoirs of 4500 m$^3$ each have been installed. A sludge pump-room serves the complex. Surplus sludge is stopped in primary sedimentation tanks and densed. Later it is pumped into pump-room reservoir. From this reservoir sludge gets into the active methane tank where the process of anaerobic digestion takes place (see Figure 1). Digesters function in mesophilic mode. The required temperature is maintained with a heat-exchange unit running a “sludge-water” programme of automatic execution. Sludge is partially warmed with the help of digested sludge using “sludge/sludge” heat exchange units. This way the temperature of sludge supplied to the digester is increased by 7-12 degrees.

![Figure 1. Scheme of Kaunas WWTP digester: 1 – reservoir, 2 – stirrer, 3 – gas accumulation storage, 4 – sludge](image)

In the course of the research technical characteristics that could affect output of biogas in digesters were observed. Such characteristics included discharge of primary and surplus sludge supplied, temperature and decomposition degree of organic materials. Discharges of primary and surplus sludge were measured with electromagnetic debitometers Promag 30. Temperature of sludge digested in methane tanks was measured with thermometers Omnigrad TST 111. Discharge of released biogas was determined with gas low meters AF 88. The
degradation degree of organic materials was found from theoretical timetable using values of sludge ash contents before and after digestion.

Data of May June, September, October and November of years 2007, 2010 2011 is suitable for analysis.

To understand the effect the stirrer has on release of biogas in digester the activity of stirrer in reservoir was halted for two weeks. Alteration in the amount of released biogas was observed when the stirrer was on and off. Measurements of the amount of sludge supplied and output gas were taken.

Effect of the degree of organic materials decomposition, temperature and sludge discharge on the factual discharge of biogas were calculated by multiple regression analysis using programme SPSS 10. The factor is held significant if \( p < 0.05 \).

Relation between yield of biogas and temperature, decomposition degree of organic materials and sludge discharge was evaluated by calculating correlation coefficients with programme STATISTICA 5. Degree of reliability was evaluated as follows: correlation was held statistically significant if \( p<0.05 \). Differences between the amount of biogas released with stirrer on and off were evaluated by using Student criterion, the difference being statistically significant when \( p<0.05 \).

Results of the research

An average of 432.5 \( m^3 \) of sludge gets into digesters of Kaunas WWTP daily. The digester under investigation at Kaunas waste water treatment plant works in mesophilic mode with temperatures varying between 32.7 and 35.4\( ^\circ \)C.

In 2007 sludge was supplied to digesters from primary sedimentation tanks, in 2010 and 2011 methane tanks were supplied with primary and surplus active sludge.

Output of biogas depends on the decomposition degree of organic materials. The decomposition degree of organic materials is determined by sludge ash contents before and after digestion. The bigger the difference between sludge ash contents before and after digestion, the better certain organic materials decompose releasing a greater amount of biogas.

Table 1 shows the dependence of biogas amount on decomposition degree of organic materials and temperature.

Effect of both factors, i.e. decomposition degree of organic materials and temperature on biogas discharge was evaluated by multiple regression analysis using model of linear regression:

\[
Y = a + b_1x_1 + b_2x_2 + b_3x_3. \quad (1)
\]

Table 1. Effect of degree of organic materials decomposition, temperature and sludge discharge on biogas discharge

<table>
<thead>
<tr>
<th>Factors of activity</th>
<th>Non-standardized coefficients</th>
<th>Standardized coefficients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constanta</td>
<td>3745.432 (a)</td>
<td>8274.798</td>
</tr>
<tr>
<td>Effect of degree of organic materials decomposition, % ( (x_1) )</td>
<td>106.734 (b_1)</td>
<td>55.851</td>
</tr>
<tr>
<td>Temperature, ( ^\circ )C ( (x_2) )</td>
<td>45.978 (b_2)</td>
<td>221.706</td>
</tr>
<tr>
<td>Sludge discharge ( q_1 ), ( m^3/d ) ( (x_3) )</td>
<td>-9.081(b_3)</td>
<td>-0.580</td>
</tr>
</tbody>
</table>

Coefficient bj shows how much Y value increases (decreases) as \( x_j \) increases by one unit when the remaining \( x_k \) are stable. \( t \) is Student criterion which determines if coefficients bj statistically significantly differ from zero and this determines if predicted values depend on \( x_j \). Standardized coefficients Beta are used to visually determine the relative influence of the independent variables on predicted value Y. By absolute greatness the greater coefficient Beta indicates the greater dependence of Y on \( x_j \). Multiple regression analysis to determine the effect of decomposition degree of organic materials and temperature on biogas discharge showed that decomposition degree of organic materials and sludge discharge had the greatest effect on biogas discharge. Biogas output was not found dependent on temperature (\( p>0.05 \)).

Scatter chart of biogas discharge and temperature is shown in Figure 2.
Biogas discharge  = -6859, + 416,09 * temperture

Correlation: r = 0,18026

Temperature, t (°C)

Biogas discharge   m^3/d

4000 5000 6000 7000 8000 9000 10000

32,4 33,0 33,6 34,2 34,8 35,4 36,0

Figure 2. Diffusion of biogas discharge and temperature

Correlation is statistically unreliable so it is possible to conclude that there is no relation between biogas discharge and temperature. Digester functions in a very narrow temperature interval of barely three degrees and this was the reason why temperature had no essential effect on the output of biogas.

Biogas discharge dependence on the decomposition degree of organic materials is shown in figure 3.

Biogas discharge  = 917,07 + 134,87 * decomposition degree of organic materials

Correlation: r = 0,22439; p = 0,045

Decomposition degree of organic materials

Biogas discharge, m^3/d

4000 5000 6000 7000 8000 9000 10000

44 45 46 47 48 49 50 51 52 53

Figure 3. Dependence of biogas discharge on decomposition degree of organic materials

Correlation is statistically reliable therefore it is possible to state that biogas discharge is dependent on decomposition degree of organic materials. The greater the decomposition degree, the greater the biogas discharge.

To assess the efficiency of operating of digester at Kaunas waste water treatment plant, theoretical and factual biogas discharge should be calculated. Theoretical biogas discharge is maximum biogas discharge that could be possibly released from the amount of sludge supplied into the digester. It is calculated for methane tanks of Kaunas waste water treatment plant. Values of theoretical biogas discharge and the factual one measured with biogas flow rate meters. The average determined efficiency of operating of digester was 83%. It would be possible to increase the efficiency of methane tank activity if more stable conditions were maintained that are necessary for smooth anaerobic process to go on.

The digester of Kaunas waste water treatment plant was also used to assess the effect of stirring sludge on the release of biogas. Amounts of biogas produced with the stirrer switched off and in normal digester mode were measured. Figure 4 shows results obtained from measurements with stirrer switched off and in a normal mode of digester.
Essential statistically reliant differences were found between biogas discharge with stirrer on and off, p=0.0001 (the difference is significant when p <0.05).

It was determined that if sludge is not stirred at all, 15-20% less biogas is released than under normal conditions of digester operating. As it was mentioned above, stirring is not the main factor affecting efficiency of sludge digestion. Composition of supplied sludge is an important factor; however, at the time of the research this factor was relatively stable. Thus, stirring has an important effect on the digestion process and improving the stirring system inside methane tank could result in even greater output of biogas.

Conclusions

Efficiency of digester activity in Kaunas waste water treatment plant is 83%.

Multiple regressive analysis showed that the decomposition degree of organic materials and sludge discharge had an effect on biogas discharge. No effect of temperature on the output of biogas in the methane tank of Kaunas WWTP was observed.

Stirring has an effect on the efficiency of sludge digestion process. When the stirrer is inactive, up to 20% less gas could be released.

Biogas output could be increased by maintaining the most stable possible conditions in the activity of methane tanks. It is worthwhile to perform reconstruction of those digesters by installing special shields in reservoirs to increase efficiency of stirring.

References

Impact of Ice Regime in the Nemunas River and the Curonian Lagoon on Floods in the Delta Area

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Abstract

The main River Nemunas of Lithuania with the length of 937 kilometers drains the area of 98,100 square kilometers having the mean runoff module of about 6.6 l/s per square kilometer. The river drains the NW part of the North Belarussian Plain as well as it collects water from a hilly and laky Lithuanian plain. Then it enters the Curonian Lagoon, which is a transit basin on the fresh water way to the Baltic Sea. The climatic conditions within the area depend on the solar radiation and the circulation of the atmospheric air masses usually moving from the West to the East. In winters the River Nemunas is usually covered with ice. In previous decades about 40% of the river runoff was usually observed during the spring floods (from February to April). During the extreme spring floods the water level can reach the height of even 8 meters above the 0 level with the sequent flooding of living areas and agricultural fields in the lowlands. The most important and dangerous phenomenon to mention is the occurrence of rather frequent flood events in the lower part of the river. The tendency is evident by analyzing the available level-gauge data of the River Nemunas that have been reported since 1812 from Smalininkai river level gauge, situated 112 km up from the river mouth. Moreover, during the recent decades the major changes in the river hydrological regime have taken place as a result of significant changes in climate.

The intention of this study is to analyze the long-term observations of river level runoff and ice regime data in Smalininkai and data of the water level and ice regime in Nida hydrological station, situated on the shore of the Curonian Lagoon. The aim is to find the relationship between the fluctuations of the mentioned parameters and the readings of flood water level on winter and spring with the prediction of situation in the river Nemunas Delta that stretches within the area of approximately 2200 square kilometers as well as in the Curonian Lagoon.

Introduction

The drainage area of the River Nemunas is one of the most significant catchments of the Eastern Baltic rivers that covers the area of 98,100 km². The length of the river is 937 km. The Nemunas River with quite high average runoff of 6.6 liters per second from sq. kilometer drains the North-Western part of the North Belorussian Plain and the Lithuanian more hilly and laky plain (Fig. 1). Other citation sources provide various runoff figures showing the significant temporal fluctuations in the flow regime (Gailiušis et al., 2001). The climate of the area mostly depends on the solar radiation and circulation of the air masses usually moving from the West to the East. The climate is soft continental. The differences between the warmest and coldest months range within 22-23°C. The annual level of precipitation is about 850 mm and about 30% of it gets into the rivers. About 40% of the river runoff occurs to be during spring flood within the period from February to April (Jablonskis et al., 1993). It must be mentioned that appearance of floods during other seasons, especially during autumn and summer is not as rare as it was several decades before. During winters water flood frequently appears and sometimes it becomes similar to spring flood in figures when the air temperature is significantly higher than the average. The mean annual discharge of the river Nemunas at Smalininkai is 540 cubic meters per second and fluctuates from minimum runoff of 92 cubic meters per second on December 23, 1953 and 151 cubic meters per second on July 21, 1964 to maximum such as 6822 cubic meters per second that occurred on April 12, 1829 (Dubra J., 1993).

During 20th century the constantly increasing navigation in many areas promoted to the formation of the non-stable ice cover. It is evident in the sea port and some navigable areas. The ice cover could be artificially broken by special boat, detonation and ice melting by strewing the peat and salt mixture on sunny days. These measures will be discussed in the paper in order to diminish the consequences of the flood in the delta of the river Nemunas and sometimes in the Curonian Lagoon. The positive components of the balance of the Nemunas River are precipitation and snow melting. The impact of the ground water is more considerable during dry summer and significantly weaker during the other seasons. The lower river level occurs during cold and prolonged winters.

The goal of this work is to analyze the long time ice cover observations in Smalininkai and to define the relationship between the fluctuations of the air temperature and the state of the ice cover in the Curonian Lagoon. These relationships are of primary importance investigating the flood events in the Nemunas Delta area, because the duration of the stable shore ice and the last ice plays a great role in the significant water level rise process having a sequent and extremely negative impact on dwelling areas of several thousands of people. According to its hydrological regime, the ice regime in the Curonian Lagoon has the right impact on the processes in the Delta area of the Nemunas River.

Methods and materials

This presentation is based on the systematical investigations of the water level, river runoff and ice regime data that has been collected in the level gauge station in Smalininkai, situated 112 km from the river mouth, since 1812 (Kolupaila, 1930; Hydrological Annals, 1945-1990) with some omissions from 1943 to 1946 during the World War II. The Nemunas River has no level gauge station, which could perform the observation of ice and escape from anthropogenic impact. The long-term meteorological observations have been available since 1777 in Vilnius, since 1848 in Kaliningrad and since 1881 in Klaipeda. The ice data for investigation were taken from Smalininkai for the Nemunas River and from Nida for the Curonian Lagoon. The data were chosen because of the longest duration of observations. Smalininkai ice data have been available since 1812 and Nida ice data have been available since 1901.
The observations of the ice cover were started in the Curonian Lagoon only in the beginning of 20th century with some gaps during the wars (Seina & Palasuo, 1993). In 1959 the dam of 16 meters of the Kaunas Hydropower station was constructed. It was situated about 100 kilometers from Smalininkai. The operational impact of the mentioned dam often results to the surge wave that is the 1-2 meters high at the start point and gradually diminishing on the move down (Ždankus & Sabas, 2006). In 1976, when the other significant dam within the catchment was erected at Vileika (Belarusian Republic) in the upper reaches of the Neris, which is the major tributary of the River Nemunas (Fig. 1). The dam is about 500 km up the river from Smalininkai and its impact on the ice regime near Smalininkai is very weak.

![Scheme of the Nemunas River catchment and the Curonian Lagoon](image)

**Figure 1. Scheme of the Nemunas River catchment and the Curonian Lagoon**

**Discussion**

The aim of this paper is based on several hydrometeorological factors having the primary importance for the water level rise. Those are terms of main ice phases and the average air temperatures of the month and the sequent runoff figures.

Fast drop down of the air temperature to the negative values results to the ice forming in the water bodies. The ice regime depends thoroughly on the duration of low air temperature and the intensity of dynamic processes in the aquatic bodies. The very first forms of ice in the Nemunas River near Smalininkai usually appear in the last days of November. Usually ice is formed in the beginning of December, but in 1875 and in 1881 it appeared in the last days of October. During the winter of 1974/75 the first ice appeared only on February 10th, but it was thawed just after 10 days. During this last mentioned winter only drifting forms of ice were observed. After 2-3 weeks following the first ice appearance, a stable ice cover formed. During the third decade of March a broken ice cover is observed thus resulting to the parallel phase of high flood water. The latest ice was observed in the end of April. The most prolonged ice period occurred from the 20th of November in 1838 to the 28 of April in 1839. Respectively the shortest period that lasted 9 days was in 1974/1975. Only during prolonged winters ice cover lasts till the end of April. During the last thirty years a tendency of weakening of ice processes resulting to the significantly dropped ice duration has been observed (Table 1).

<table>
<thead>
<tr>
<th>Ice Stage</th>
<th>First ice</th>
<th>Stable shore ice</th>
<th>Cracked ice</th>
<th>Last ice</th>
<th>Number of ice days</th>
<th>Number of ice cover days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medium (day.month)</td>
<td>30.11</td>
<td>18.12</td>
<td>21.03</td>
<td>26.03</td>
<td>87</td>
<td>108</td>
</tr>
<tr>
<td>The earliest (day.month)</td>
<td>30.10</td>
<td>08.11</td>
<td>22.12</td>
<td>03.01</td>
<td>134</td>
<td>151</td>
</tr>
<tr>
<td>Year of the earliest</td>
<td>1875, 1881</td>
<td>1919</td>
<td>1924</td>
<td>1989</td>
<td>1830</td>
<td>1909</td>
</tr>
<tr>
<td>The latest (day.month)</td>
<td>10.02</td>
<td>-</td>
<td>-</td>
<td>28.04</td>
<td>0</td>
<td>9</td>
</tr>
<tr>
<td>Year of the latest</td>
<td>1975</td>
<td>1975</td>
<td>1975</td>
<td>1839</td>
<td>1975</td>
<td>1975</td>
</tr>
</tbody>
</table>
The recent decades show significant decrease of number of ice days and especially the stable shore ice days by 1.5 to 2 times. Some aspects are raised by the introduction of the Hydropower Plant of Kaunas partly changing the ice regime down the river. Thus, the presence of the plant and some long-term riverine processes including sediment transport reduction with consequent change of the river bed resulted to the slightly reduced parameters of rating curve at Smalininkai (Fig. 2). It must be mentioned that water reservoir on the mentioned plant can hold the volume of the river runoff of 1% probability for only 1.5 to 2 days. On the other hand, this can be possibly explained by the global warming processes consequently working on local scale.

During spring flood the water level can reach ever 8 meter height. The lowest water level forms during cold and prolonged winters. We noticed that the duration of ice days in Smalininkai has good relationship to the mean winter air temperature in Vilnus (Fig. 3). Data from Vilnus was chosen due to the longest period of observations.

![Figure 2. Variations of the stage-discharge rating curve in Smalininkai in the 4th decade of the 20th century and the 1st decade of the 21st century](image)

![Figure 3. Long-term variations and trends of the mean winter air temperature and the number of ice days in the River Nemunas](image)

The comparison of the ice regime in Smalininkai to the observations in the lagoon at the head post at Nida showed the similar annual tendencies and the same average terms of the main phases of the ice characteristic during the period of the last 200 years (Fig. 4a). The average number of ice days is decreasing slightly faster while the mean air temperature of the winter season is increasing (Fig. 6).
Figure 4. Relationships: a) between the duration of the formation of new ice in the Curonian Lagoon and the Nemunas River near Smalininkai. \( Y = 5.12 + 5.71 \times X \); b) between the duration of the formation of cracked ice in the Curonian Lagoon and in the Nemunas River near Smalininkai. \( Y = 0.58 + 0.79 \times X \)

The waters of the River Nemunas first get to the Curonian Lagoon then taking the direction to the Baltic Sea. The Curonian Lagoon is a fresh water body that is formed of the water entering from the Nemunas River but the northern part of it is marked with the intrusions of the salty marine water, because of the storm surge activities. Some of the authors regard the Curonian Lagoon to be the continuation of the Nemunas River delta (Basalykas, 1958). The ice regime of the Curonian Lagoon looks similar to that of the investigated river near Smalininkai (Figs. 4a, 4b), except the duration of the stable ice shore (Fig. 5a). The differences of the last case in both the water bodies occur because of the differences in the runoff regime.

The significant difference could have been noticed for several years when the advection of cold has been playing a significant role in near the sea coast area and even further from it. Although in most the cases we have the same tendencies of the variations of the ice regime phases. Consequently, it let to apply the long-term observation data from Smalininkai for the ice regime in the Curonian Lagoon. Analysis of the ice regime data represented as the decade principle shows the significant decrease of the duration of the ice days and especially the shortage of the presence of stable ice shore, which lasts 2 times shorter than in the beginning of the 20th century (Fig. 6). Drastic changes in the ice regime took their beginning in the eighties of the last century. Considering the occurrence of the period of mild and mostly relatively warm winter periods the probable duration of such a trend could be the object for further discussion.

Figure 5. Relationships: a) between the duration of the stable shore ice in the Curonian Lagoon and in the Nemunas River near Smalininkai; b) between the mean winter air temperature and the number of ice days in the Nemunas River near Smalininkai.

The average duration of the ice cover ranges within the period of 3 months, but during the last years that could be characterized as having the extreme meteorological parameters. The period can be prolonged to the period of 5 months or even hardly be formed. The ice period during very cold winter of 1838/39 lasted for 160 days but during very soft winter of 1974/75 the duration was only 11 days. The average thickness of the ice is about 40 cm but during the cold winters it can reach 60 centimeters and even more. Then the thickness of the ice is higher (about 80 cm) and the water level fluctuations are more significant, but the current velocity in the Curonian Lagoon is lower than in the River Nemunas.
After the relatively cold period that lasted during the previous century, especially in the recent decades the ice regime and weather conditions have become milder (Fig. 3). It reveals the tendencies of climate warming in our region as well. After very cold period in 1939-1947 we have had mostly warm or mild winters. The latest cold winter occurred in 1986/87. The tendencies of the climatic regime in the Nemunas Basin are similar to those in the neighboring countries.

In the last three decades (Fig. 6) the ice cover that formed on the River Nemunas was stable only for 2 months in average. In comparison to the first half of the last century the ice period was 3-3.5 months’ long. The duration of ice presence in the river took the similar changes. This period has shortened from 4 to 3 or even to 2.5 months.

The other important relationship based on the long-term data was observed between the mean winter air temperature and the number of ice days in the Nemunas River near Smalininkai (Fig. 5b). This relationship pays tribute when assessing the impact of the basically measured parameters of the air on the runoff volume. Long-term trends of the mean annual runoff of the River Nemunas are shown in Fig. 7.

The most significant changes occur during the spring period. Drastic reduce of the runoff with the consequent disappearance of frequent flood events is observed during April and May. Tendentially, the major water volume flows down the river during February and March especially. It can be explained by appearing of flood events from late winter to early spring.

In comparison, earlier they occurred in the very middle of spring. One of the positive trends could be the total disappearance of relatively cold winters from November to January when a stable shore ice cover forms. These facts still have no statistical importance in order to change the existing long-term trends, but their importance for the future is an object for serious discussion. It must be mentioned that the global Greenhouse Effect plays a great role in such variations occurring on the local scale.
Conclusions

The ice regime in the River Nemunas near Smalininkai has the same annual trends and approximately the same average terms of the ice forming phases as in the Curonian Lagoon near Nida. Only in the mouth part of the River Nemunas the duration of the ice days is about half a month longer. The relationship can be of primary importance when assessing the possible high water appearance with the consequent increase of other hydrologic parameters. During the last three decades the ice cover that formed on the River Nemunas was stable only for 2 months in average in comparison to the figures of 3-3.5 months in the last century. The similar situation is with the ice presence duration on the river. This period has shortened from 4 to 3 or even to 2.5 months, accordingly affecting the terms of floods. A very important statistical fact is that flood occurrence in the Nemunas River is changing its average terms from April and May to February and March. It must be mentioned that flood events become more significant during the cold period from November to January.

The long-term investigation and analysis of data of ice regime shows the remarkable change tendencies that are possible because of the impact of climate warming and even the global Greenhouse Effect.

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Close-Knit Communities, Examples of Community Collaboration and Innovations in Land Resources to Enhance the Tourism Product in the Sheep’s Head Peninsula, Ireland

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Abstract

With the unprecedented growth of tourism it is inevitable that sustainable planning guidelines must be adhered to. During the next decade, the tourism industry is expected to grow by an average of 4% annually to constitute 10% of global GDP (US$10 trillion) and by 2022 it is predicted that globally 1 in every 10 jobs (328 million) will be tourism-related. Sustainable management of our natural resources are now a high priority, as tourism planners attempt to avoid past problems with the mass tourism market such as the rapid growth of the Costas around the Mediterranean Sea from the 1960s until the 1990s. This type of mass or ‘fast tourism’ characterises the very antithesis of a type of tourism that is considered sustainable. Past models of tourism development illustrated little or no concern for the existing landscape, social, environmental or economic and it is hoped that the dawn of ‘slow tourism’ and more ecological approaches that are based on a valorisation of natural landscapes can remedy the problems of the past and rejuvenate rural economies.

Innovations in Land Resources to Enhance the Tourism Product in the Sheep’s Head Peninsula, Ireland

The purpose of this investigation is to examine the literature on the development of nature-based tourism in Ireland, and in particular the role providers of these land resources have in the development of the rural tourism industry. Extensive literature is available in regards to nature-based or slow tourism with a strong focus on the consumers rather than the suppliers which data is collected through tourism barometers and tourist surveys. Nature-based tourism features predominantly in rural areas and can be the primary route to development for rural communities. Nature-based tourism as described in (Newsome et al., 2002, p.11) is based on tourism in natural areas that focus on;

a) Adventure (an emphasis on outdoor activity)

b) Nature based (viewing the natural landscape)

c) Wildlife

d) Ecotourism (includes educative and conservation supporting elements)

While there is a dearth of literature available on the consumers of nature-based tourism, some gaps however exist in examining tourism with a supply focused approach. Mulder et al. (2006) stress that the majority of research in rural access found in the public domain has been based on the demand side, and has tended to ignore the supply side. Multiple case study analysis conducted in the United Kingdom (Evans, 2004; Land Use Consultants, 2004; ADAS Consulting Ltd, 2003; Leisure Industries Research Centre, 2003 and Trevelyan, 2003) analysed the needs of walkers with a demand focused approach and did not address or quantify issues of concern to landowners. This paper discusses innovations in land resources as a means to develop the local area from the supply side of the tourism product.

Commodification of the landscape

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Case study analysis – Sheep’s Head Way

The case study area in this study is a peninsula called the Sheep’s Head which is located in West Cork, Ireland. West Cork (as seen in Figure. 1) according to the West Cork Development Partnership (2012) is an area that covers 2,170km² and has an indented coastline that spans over 550km. The economic base of West Cork is constructed of small towns and villages that are inextricably linked to their rural hinterlands. Economic disadvantage in West Cork stems largely from topography and access (O’Reilly and Cashman, 2008) so it is essential that the region utilises what resources they do have to their full potential. The county of Cork has an average population density of 31.6 persons per km² which is nearly half of the national average of 60.56 persons per km² (GAMMA, as cited in O’Reilly and Cashman, 2008). This low population density and the presence of highly specialised industries have resulted in recreation and tourism becoming an integral component to the local economy.

The Sheep’s Head Way is also known as Sli Mhuintir Bhaire extends out towards the Atlantic Ocean in between Bantry Bay and Dunmanus Bay. The walkway spans over 88km and also contains looped walks that

1 REPS (Rural Environment Protection Scheme), is a Scheme designed to reward Farmers for carrying out their farming activities in an environmentally friendly manner and to bring about environmental improvement on existing farms. Establish farming practices and production methods which reflect the increasing concern for conservation, landscape protection and wider environmental problems. Protect wildlife habitats and endangered species of flora and fauna. Produce quality food in an extensive and environmentally friendly manner.

2 The Sheep’s Head is not an administrative unit; it has natural boundaries such as Dunmanus Bay and Bantry Bay. For statistical purposes, I am including eight DEDs. A DED or district electoral division is a former name given to a low-level territorial division in Ireland, they are the smallest legally defined administrative areas in the state. Seniūnija (elders or eldership in English) is the equivalent of a DED and is the smallest administrative division of Lithuania.
encroaches into other neighbouring walks such as the Drimoleague walkway (Dillon, 2010). This neighbouring walk is known as the Sheep’s Head Eastern Trail which is 52.5km in length and runs through the villages and towns of Bantry, Drimoleague and Gougane Barra (URS Scott Wilson, 2012). The walkways on the peninsula traverse through a landscape of outstanding natural character and the inclusion of the adjacent islands of Bere, Dursey, Garnish and Whiddy are additional draw factors for the visitor. These islands combined with the raw beauty of the landscape strengthen the appeal of the destination and provide a ‘unique selling point’ that differentiates the routeway from other walking destinations in Ireland and the UK (URS Scott Wilson, 2012). Visitors to the area have followed this trend towards the consumption of the countryside and coastline and the importance of tourism to the area is evident in estimated tourist figures. A West Cork Development Partnership report published in 2012 reported that in 2009 the industry generated around 470,000 tourist visits which led to the generation of €134 million in revenue for the region.

Figure 1. Case Study Area of West Cork

Sustainable local development

An essential component of rural tourism development is often cited as the sustainable management of the landscape and the establishment of regional and local partnerships (Cawley et al., 2007). Genot as cited in Fennell et al., (2007) mirrors this theory and states that the primary obstacle to environmentally sound tourism management can be attributed to the lack of co-operation and collaboration between tourism stakeholders. However the success of the Sheep’s Head Way as a tourist destination can undoubtedly be linked to strong community links, collaboration and the innovative yet sustainable use of the landscape as a resource. The walkway is an example of a tourist product where individual community members have through their own initiative and with the added assistance of outside funding developed a successful, rural tourism business, based on nature-based walking tourism. As seen from Figure. 2 the route way traverses over 300 farms and was only made possible through the cooperation of all landowners, as nearly all of the utilised land is privately owned. This case study area can be described as a project that reflects methods of best practice and an innovative use of land resources. The methods used to achieve the success of the project could be utilised as a benchmark for other similar walking tourism projects. The marketing strategy for Sheep’s Head Way has drawn inspiration from a highly successful walking route already in place, Loop Head in County Clare. This walk way

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3 From initial interviews during the first stages of data collection, it was reported that certain sections of the walkway traverse through commonage land. Commonage land is land used by multiple landowners and has no single owner.
was voted the best tourist destination in Ireland from a poll in an Irish Newspaper ‘The Irish Times’ in 2013. Mr. John Tobin who is the chairperson of the Sheep’s Head and Bantry Tourism Co-operative (SHBTC) stated that from the outset, we have been working towards developing a plan like the one that was used on the Loop Head peninsula in County Clare... we need to work together, and promote ourselves actively in order to win a substantial share of the available tourist market (Keogh, 2013, p.1).

One major issue in regards to local development in rural areas in Ireland is often the lack of local ownership of the community, or in a physical sense the lack of local ownership of land. This is often the case in idyllic settings where affluent ‘outsiders’ purchase holiday or second homes and this is evident along the West Cork coastline. It is estimated that along Cork’s scenic peninsulas, over a third of houses are holiday homes (Cork County Council, 2006).

**Rapid growth of walking tourism**

Walking trails and routes have developed rapidly in recent years in many upland areas and also through farmland that is not being intensively used for agricultural purposes. The Sheep’s Head Way is an area of low agricultural output and is an ideal location for the development of these trails. Recreation is now fast replacing agriculture as the single greatest land use and recreational activities such as tourism can be developed through a conservation and sustainable led way (Stelfox, 1995). Walking activities is one of the largest participation sports undertaken by Irish residents\(^4\) and this is mirrored in tourism numbers engaging with walking activities as in 2009 over 800,000 visitors engaged in walking during their holiday to Ireland (Ireland, Department of Transport, Tourism and Sport, 2011). Persons engaging in recreational walking has increased by (+ 4.1%) from 2007 to 2011 so its growing popularity could signal future development for walking trails that can be also utilised for tourism development (The Irish Sports Council, 2011). Walking tourism in the Sheep’s Head is considered a sustainable method of generating revenue for the local community and it can be used as a means to complement conventional agricultural activities.

![Figure 2. Building walking capacity on the Sheep’s Head Way](source: URS Scott Wilson (2012))

West Cork in particular has witnessed an increase of tourism based on ‘green’ sectors of the industry and this can be contributed to innovations of local land resources. These include; walking and cycling trails, outdoor attractions, gardens, national forests and parks, water based activities, bird watching, agri-tourism, historical sites and island trails. All of these types of activity are signature of the character of incoming tourists whom demand to interact with Ireland’s natural environment. Fundamentally, this type of nature-based or ethical tourism is a theme that has emerged in response to worldwide concerns about the impact of mass tourism. This type of tourism not only benefits the landscape, but has the potential to benefit of all stakeholders in the nature-based tourism process. This type of ethical tourism also emphasises the importance of limiting the negative impact of tourism on the host community whilst at the same time

\(^4\) 46% of the adult population of Ireland (1.5 million people average) participate in recreational walking, 3% Cycling (Lunn and Layte, 2008).
providing sustainable economic benefits for the host destination (Butler, 1992). Tourism ethics in partnership with nature-based tourism activities stem from sustainable development literature. Genot (1995) identifies six primary issues at the core of codes of ethics for this type of nature-based tourism, she also states that they can be generalised across the board in reference to the environmental aspects of tourism, including:

1) The expression of overall environmental commitment;
2) Recognising the importance of taking responsibility
3) The integration of tourism planning and development with other land-use policies;
4) The importance of environmental management practices (e.g. audits)
5) Co-operation between different decision-making groups; and
6) Making the public aware at all levels.

( Genot as cited in Fennel et al., 2007, p.66)

Assuredly tourism providers and tourists themselves have different motives when it comes to economically developing or consuming the tourism product, but both parties should at least be talking the same language with respects to the protection of the ecological integrity and socio-cultural values of the region. A significant majority of academic literature argues that there needs to be a tailored version of sustainable development in the form of sustainable territorial development. Valentine (1992) argues that a similar approach be considered when discussing codes of ethics for tourism, and a tailored approach is also necessary to fulfill the needs and expectations of different groups in the same setting. However, Weeden (2005) also suggests that tourism providers have expressed concern over too many codes of ethics in existence which may confuse tourists. This may be in the form of ‘brand soup’ where ethical practices such as ‘eco-friendly’ and ‘sustainable’ loose their ascribed meaning due to an excess of logos or awards on tourism products. In many circumstances there has been evidence of ‘ethical wash’ where industry codes are not supported by the tourism providers themselves, this may be due to lack of regulation or poor enforcement guidelines.

Reseaching the narrative and methodology used

In order to comprehend the narrative of the Sheep’s Head Way preliminary interviews were carried out with landowners and farmers that participated in the walkway. Semi-structured interviews that were on average one hour in duration were held on site and a pilot questionnaire was handed out to all six landowners. A narrative was compiled from this data and a story emerged about the transformation of what was once a barren peninsula to an EDEN award winning walkway. The preliminary investigation of the case study area signalled a high proportion of farmers participating in Rural Environment Protection Scheme (REPS) so maps were created from Central Statistics Office (CSO) data. From this data it was evident that the majority of the Sheep’s Head peninsula has between 50-100% of farms in receipt of REPS payment. This payment can be contributed as part payment for the upkeep of the walkway and is valued on a per hectare basis. However as well as farmers there are are many other stakeholders of the walking tourism product including; residents, farmers, fishery and forestry enterprises, local industry and services, providers of tourist accommodation and attractions and recreational users, state agencies and local authorities are also stakeholders (Nugent, 1995). An impending census of the full peninsula will reveal many behavioural and attitudinal data across all stakeholders in the area.

Preliminary results of research

As this study is still at an early stage, intial findings suggest varied attitudes towards sustainability of the environment, economic and social benefits of the walkway and also mixed feelings about levels of community collaboration. Already from the data compiled examples of ‘good practice’ of green or nature-based tourism emerge from the interviews undertaken in this study. As seen from Table.1 it is clear that the Sheep’s Head way is the opposite of conventional mass tourism through the examples of good practices as listed. The interviews also revealed specific examples that illustrate the experienced benefits and challenges that emerge from the walking route. From the literature reviewed it is evident that tourism brings tangible benefits to a local community such as economic gain, an improvement in infrastructure and services, and a visible increase in tourist presence. Tourism however also provides intangible benefits such as social cohesion and new networking opportunities, conservation of the environment and landscape, and destination branding.

Nature-based tourism often reflects stronger evidence of intangible benefits to the host community. When asked ‘Have you experienced any benefits from the walkway?’ one interviewee responded;

Oh yes defiantly, it is definitely bringing people to the area and it is very well known as a walking route since.
I mean it has definitely drawn a lot of people to the area; there is no doubt about that. There is a lot of extra developments there is a lot of places that have expanded things as a result.

(Interviewee No.3)
The projected future results of this investigation will have an in-depth focus on rural tourism activities, as generally speaking nearly all of walking tourism ventures occur in rural spaces. Although farm-based tourism has been the core of a majority of agricultural activity especially within Europe, farm diversification into tourism has, in recent years, become an acceptable means of addressing the socio-economic problems of rural areas (Sharpley and Vass, 2006). Modern agriculture is multifunctional and can be defined as “not only producing food but also sustaining rural landscapes, protecting biodiversity, generating employment and contributing to the viability of rural areas” (Potter and Burney, 2002, p.35).

**Table 1. Sheep’s Head Way – examples of best practice of green tourism activity**

<table>
<thead>
<tr>
<th>MASS TOURISM</th>
<th>GREEN TOURISM</th>
<th>Sheep’s Head Way examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Development without planning</td>
<td>First plan, then develop</td>
<td>Development of Sheep’s Head way development group who consulted with all landowners.</td>
</tr>
<tr>
<td>District level planning only</td>
<td>Regional co-ordination of district plans</td>
<td>Co-ordination of plans to integrate the Drimoleague walkway.</td>
</tr>
<tr>
<td>Building outside existing settlements</td>
<td>Development within existing settlements</td>
<td>Developed the walkway on existing pathways and shared commonage land.</td>
</tr>
<tr>
<td>Intensive development in areas of finest landscapes</td>
<td>Fine landscape conserved</td>
<td>No railings or invasive signage was installed as part of the walkway.</td>
</tr>
<tr>
<td>New building and new bed capacity</td>
<td>Re-use existing buildings-better utilisation of bed capacity</td>
<td>Farm houses converted to Bed &amp; Breakfast and hostels. No evidence of any new development to facilitate bed capacity.</td>
</tr>
<tr>
<td>Development by outside developers</td>
<td>‘Native’ developers only</td>
<td>Local people developed the idea and invited other members of the community to get involved.</td>
</tr>
<tr>
<td>Employment primarily for non-natives</td>
<td>Employment according to local potential</td>
<td>Local tour guides charge a minimal fee for groups of walkers.</td>
</tr>
<tr>
<td>Development only on economic grounds</td>
<td>Discussion of all economic, ecological and social issues</td>
<td>Consultation was evident among land owners with regards to the best possible route for the walkway. The area is also host to Special Area Protection status.</td>
</tr>
<tr>
<td>Farming declines, labour forced into tourism</td>
<td>Farm economy retained and strengthened</td>
<td>‘to be investigated’</td>
</tr>
<tr>
<td>Community bears social costs</td>
<td>Developer bears social costs</td>
<td>As the walkway traverses over 300 farms the developer essentially is the landowner who shares the opportunities and challenges of the walkway.</td>
</tr>
<tr>
<td>‘Natural’ and historical obstacles removed</td>
<td>‘Natural’ and historical obstacles retained</td>
<td>Old famine ruins such as buildings and potato rows preserved as part of the natural landscape.</td>
</tr>
</tbody>
</table>

Source: Adapted from Butler (1992) and Lane (1988), Table. 1 has been constructed from the initial interviews at the primary stages of data collection.

Another respondent highlighted the transformation of existing buildings to provide bed capacity for the walkers. When asked about accommodation facilities for walkers one interviewee stated “Yes there is a B&B and self-catering place completely rebuilt just down across the fields from us here” (Interviewee No.1). There was also evidence of improvements to infrastructure which does not only benefit the tourist but also the local community. One interviewee highlighted the fact that some dangerous roads along the peninsula were widened, and finance only became available due to the success of the walkway. “Yes there were bits of work done there too (the roads), we have managed to get bits of finance and bad bends and things we have improved along the way” (Interviewee No. 4).

**Conclusions**

It is evident from the preliminary findings of this research that the development of walking tourism in the Sheep’s Head Way goes hand in hand with the conservation of the landscape. Hannam and Knox (2010) stress that by examining the interdependence of tourism and the environment we can highlight conservation efforts and value our natural resources. Issues of maintaining a low ‘carbon footprint’ has also come to the forefront of a significant amount of holidaymakers’ decisions when planning tourist travel. Nature-based tourism activities offers a means of encouraging environmental and landscape conservation and educating visitors on the importance of sustainable development. For years, there have been competing objectives between agriculture and landscape conservation and maintaining this balance is a major challenge for policy makers (Lee, 1995). There needs to be input from both providers and consumers of nature-based tourism activities in order to create a balance to tourism development. The management of the walking trails’ landscape requires proper planning and creating the optimum balance between human development and environmental protection (Nugent, 1995). In the case of the Sheep’s Head way issues of overuse of the landscape is unlikely due to the peninsulas peripheral location.
In the past rural areas were seen as places of production, a landscape to provide for the host community. Rural areas in recent times however can be considered a place of consumption, as hosts of recreational and leisure activities (Woods, 2011). Rural areas are highly reliant on agriculture to develop the local and national economy and tourism intertwined with agricultural areas can play a part in maintaining future development. The primary agricultural sector contributes 2.5% of GDP to the Irish economy in 2010; this is twice that of the EU average (European Commission, 2012). In summary it can be considered that tourism was the leading contributor to the services sector of employment creation from the years 1981 to 2005 and its contribution to GDP exceeded that of the primary sector in rural Ireland. At present in the case study area walking tourism is estimated to generate over €14 million for the economy of West Cork and supports approximately 353 Full Time Equivalent (FTE) jobs. If the region can successfully combat future challenges to walking tourism in the area and improve weaknesses in the product walking tourism in the region could contribute nearly €22 million to the area by 2016 (URS Scott Wilson, 2012). Since the majority of nature-based tourism activities including walking are often not fee-paying, local communities can only gain financial benefits by tourist’s spending money in local accommodation sites, shops, restaurants, bars and services. However the value of intangible benefits cannot be underestimated as social cohesion is an essential component for the development of rural spaces. Finally it is imperative for the tourist to understand that the rural landscape is not a redundant backdrop for the incoming visitor, landscapes are a dynamic living environment in a constant process of change.

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3 Tourism comprised 7 per cent of total hours worked in the economy in 2007, up from 6 per cent in 2000 and 3 per cent in 1980 (Forfás, 2011). Between 1965 and 2000, the number of overseas visitors to Ireland increased almost fivefold while foreign exchange earnings from tourism advanced by a factor of forty. From the years 1985-2000, tourism growth has resulted in the number of overseas visitors climb from under two million to well over six million (Tansey et al, 2002).
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Natural and Regulated Streams Stability and Self-Regulation

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Abstract

Flow dynamic processes are more steady in natural river beds than in regulated ones. The article presents the K. V. Grishanin criterion M to evaluate bed stability and self-regulation issues for natural and regulated streams. Assessing the natural streams by Grishanin's coefficient it was found that dynamic equilibrium is established and is close to one in natural rivers. According to the research it was found that natural river beds are stable enough (criterion M values ranging from 0.82 to 0.91), while sliming and silting processes are regulated ones (criterion M values ranging from 1.38 to 1.47). Comparing the data obtained by other authors researches show similar regularities, which are confirmed by K. V. Grishanin bed stability criterion M application to evaluate Lithuanian rivers stability.

Key words: streams bed stability, K. V. Grishanin criterion, regulated streams

Introduction

Natural rivers, as unique natural systems, are able to modify and adapt their beds form, sediments and the longitudinal slope (as opposed to artificially adjusted and enhanced bed). Rivers do it over a sufficiently long period of time while changing both, a bed form as well as its position in the plan, regulating the bottom surface roughness and sediment leaching and deposition (River. ..., 1998). Self-regulation processes of natural streams take a long time under stable climate conditions. That lets to evolve river into a stable constant width and depth of the beds in which the local flow accelerations change the slowdown, while the average velocities and longitudinal slope remain almost constant. An almost constant and comparative river flow of energy loss at the same time stabilizes and remains constant.

Based on research (Leopold, Rosgen, 1991) naturally formed rivers in the natural environment and stream flows of self-regulation and their interaction with the river furrows suggests that while designing their beds, all of them conform for the minimum energy law. This means that the flows of these rivers and their beds interaction through a historically long period of time evolve towards a dynamic equilibrium in such a way that the current conditions of flow potential energy comparable loss of water and sediment transport would be the lowest (Stream ..., 1998). Therefore, for any reasons, natural flow can also change its bed or adapt to new conditions, depending on the change of the water and sediment flow (River. ..., 1998; Newsletter ..., 1998). This show to both, the river bottom sediments form adaptation, as well as the bed forms and meanders changes or periodically flooded valley areas of vegetation cover change (Schumm, 1997). The river-bed stability, development and adaptation to changes in flow and sediment transport conditions patterns were examined in the last century mostly for medium size and large rivers (Lane, 1955; Schumm, 1977). Thus, it becomes important to investigate, analyse and evaluate such beds deformation conditions and reasons, to evaluate their riverbed processes as well as intensity for Lithuanian conditions.

The aim of research - to evaluate stability of regulated and natural streams (Spengla, Amarnia, Grūda) in Merkys river basin according to the selected river bed hydrodynamic stability criteria.

Materials and Methods

Research was carried out in three medium-sized Merkys Basin rivers: Amarnia, Grūda, Spengla. Amarnia – the right tributary of river Merkys, flows out of the lake Nedzings. The length of river 15.1 km, the catchment area - 144 km². The river is regulated from spring to 10 km. Grūda - the left tributary of river Merkys. The source of river is in Grūda lake in Belarusian forest, near the Lithuanian-Belarusian border. The length of the river is 36.2 km, the catchment area is 248.4 km². The river is regulated from spring to 22.2 km. Spengla – the right tributary of river Merkys. The length of the river is 25.9 km, the catchment area is 148.3 km². The source of the river is in Spengla lake. The middle reaches of the river are adjusted (from 19.6 to 13 km) (Gailiušis et al., 2001). The object of research location map is shown in Figure 1.

Figure 1. Sections of studied rivers in Merkys river basin (The numbering corresponds to Table 1)
Table 1. General environment parameters of the investigated section of the streams (RL - straightened section in field, NT - natural section in forest)

<table>
<thead>
<tr>
<th>Streams</th>
<th>Sites N.</th>
<th>Section</th>
<th>Locality</th>
<th>Discharge m³/s</th>
<th>Average width m</th>
<th>Average depth m</th>
<th>Current velocity m/s</th>
<th>River-bed overgrow with plants %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amarnia</td>
<td>1</td>
<td>RL</td>
<td>54° 15' 43&quot; N, 24° 19' 52&quot; E</td>
<td>0.83</td>
<td>5-7</td>
<td>0.5</td>
<td>0.3</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>NM</td>
<td>54° 14' 21&quot; N, 24° 21' 03&quot; E</td>
<td>1.32</td>
<td>6-7</td>
<td>0.5-0.9</td>
<td>0.6</td>
<td>5</td>
</tr>
<tr>
<td>Grūda</td>
<td>3</td>
<td>RL</td>
<td>54° 01' 54&quot; N, 24° 20' 14&quot; E</td>
<td>0.92</td>
<td>5-7</td>
<td>0.4-0.6</td>
<td>0.5</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>NM</td>
<td>54° 07' 05&quot; N, 24° 19' 20&quot; E</td>
<td>1.79</td>
<td>5-8</td>
<td>0.6-0.8</td>
<td>0.6</td>
<td>5</td>
</tr>
<tr>
<td>Spengla</td>
<td>5</td>
<td>RL</td>
<td>54° 23' 25&quot; N, 24° 43' 12&quot; E</td>
<td>0.58</td>
<td>6-8</td>
<td>0.5</td>
<td>0.3</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>NM</td>
<td>54° 21' 07&quot; N, 24° 47' 05&quot; E</td>
<td>1.34</td>
<td>7-9</td>
<td>0.5-1.2</td>
<td>0.5</td>
<td>5</td>
</tr>
</tbody>
</table>

Methodology of research

Selected rivers bed sections were divided into cross-sections every 1 meter. Rivers bed width (b) and average bed depth (d) were determined in every cross-sectional areas. Flow velocities and discharge were measured using acoustic device "StreamPro ADCP". GPS GeoXH receiver was used to determine position in space (x, y coordinates) of "StreamPro ADCP" device in the open furrows. In cases where the woody vegetation covered bed and the use of GPS was not possible due to major errors, the geodimeter device was used, which data is coordinated by GPS device. Streams coastline was measured by GPS device or geodimeter.

Riverbed points (Figure 1. a) with flow velocity and depth values were interpolated by geostatistical methods with program ArcGIS 10.1. After that the bed depth and flow velocity surfaces (GRID) are received. With the help of these values the average of Froude number was calculated for the investigated sections of rivers. Froude number characterize river flow kinetic and potential energy ratio in measured cross section. Froude number is defined as:

\[ Fr = \frac{v}{(gd)^{1/2}} \]  

here:  
- \( v \) - the mean velocity in river cross section, m/s;  
- \( g \) – acceleration due to gravity, m/s²;  
- \( d \) – average bed depth in river cross section, m.

In order to assess the stability of the bed K.V.Grishanin, famous hydraulics professor, observed and applied bed stability criterion M (Grishanin, 1969, 1971, 1972, 1979, 1990, 1992). The professor analyzed the well-established, slow-changing natural currents and found an open alluvial bed stability criteria, linking it to form the bed of the formative flow stream energy (Grishanin, 1971):

\[ M = \frac{dgb^{1/4}}{Q^{1/2}} = \left[ \frac{d}{b \ Fr^2} \right]^{1/4} \]  

here:  
- \( M \) - the Grishanin dimensionless rivers bed stability coefficient;  
- \( d \) – average bed depth in river cross section, m;  
- \( b \) – river bed width in river cross section, m;  
- \( Q \) – bank full discharge, m³/s;  
- \( g \) – acceleration due to gravity, m/s²;  
- \( Fr \) - dimensionless Froude number.

Values of calculated criterion M were compared with the study results of other researchers. Following the comparison of results the reliability of the criterion was analysed by using it to evaluate the stability of Lithuanian rivers.

Results and Discussion

According to the above mentioned methodology the surfaces of riverbed points (Figure 1. a), riverbed depths (Figure 1. b) and flow velocities (Fig. 1. c) are presented. Using formula No 1, after mathematical calculations, the average values of Froude number are presented (Figure 1. d).
According to available data, beds stability criterion, described as K.V.Grishanin stability factor (M) (formula (2)), are calculated. K.V.Grishanin coefficient values distribution in researched streams are presented in Figure 2.

![Figure 1. Data processing schemes](image)

![Figure 2. The distribution of K.V.Grishanin coefficient values in cross-sections of surveyed streams](image)

K.V.Grishanin factor (M) ranged from 1.18 to 1.56 in investigated Amarnia stream regulated stretch. The average value is $M = 1.38$ of this section. Criterion M ranged from 0.55 to 1.15 of Amarnia stream natural stretch. The average value of $M = 0.91$. Bed stability coefficient ranged from 1.20 to 1.82 of Grūda stream regulated bed. The average $M$ value is 1.47. Significantly lower value $M = 0.89$ was determined in natural river section. Criterion M ranging from 1.14 to 1.77 was found in Spengla regulate stretch, the average value is 1.44. K.V.Grishanin factor (M) ranged from 0.51 to 1.26, which averaged 0.82 in Spengla natural stretch.

Summarized results of natural and regulated sections survey are presented in Table 2.

<table>
<thead>
<tr>
<th>The name of stream</th>
<th>Natural stream</th>
<th>Regulated stream</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amarnia</td>
<td>0.91</td>
<td>1.38</td>
</tr>
<tr>
<td>Grūda</td>
<td>0.89</td>
<td>1.47</td>
</tr>
<tr>
<td>Spengla</td>
<td>0.82</td>
<td>1.44</td>
</tr>
<tr>
<td>Average</td>
<td>0.87</td>
<td>1.43</td>
</tr>
</tbody>
</table>

It was found that the average bed stability factor is $M = 0.87$ in natural stream sections. Meanwhile, the average of stability factor is 1.43 in regulated streams. This confirms that slimming and sedimentation processes are going on in regulated streams.

Summarizing the above mentioned separate sections of the results a statistically significant ($p < 0.05$) difference between the stability coefficients of regulated and the natural beds was determined.

According to K.V.Grishanin, in plain rivers it is likely when $M < 0.90$. The bed becomes stable when $M > 0.92$, while for $M > 1.1$ silting and sedimentation processes are likely.

Comparing these results with the boundaries of coefficient values presented by K.V.Grishanin one can notice that the investigated natural rivers (Amarnia, cereals, Spengla) are close to the natural watercourses with occurring small erosion processes. Meanwhile, silting and sedimentation processes are determined in regulated researched stream stretches.

According to the research carried out by other researchers (Vaikasas et al., 2013) significant differences of K.V.Grishanin coefficient between natural and regulated river beds were determined. K.V.Grishanin coefficient values are...
respectively 0.81 and 0.87 for natural Kumė and Maišys stream sections. In the regulated Kume section coefficient $M$ value is only 0.68. The results show that the stability criteria $M$ of natural watercourses compared to regulated sections are significantly closer to 1. However, criterion $M$ value is less than 0.90 for the researched rivers sections. This indicates that bed stability has not yet been sufficient in natural Maisys and Kume rivers (respectively, $M=0.87<0.92$ and $M=0.81<0.92$). Meanwhile, this stability criterion is only $M=0.68$, i.e. $0.68 << 0.92$ for the regulated Kume river section. This shows that the regulated section is very unstable, and it is still under intensive bed regeneration process. In that case the river bed will be able to stabilize naturally just over a sufficiently long period of time.

Comparing results published in the article and results of other researchers (Vaikasas et al., 2013) there is a clear relation between the processes in natural streams, - values of K.V.Grishanin coefficient ranging from 0.81 to 0.91. Meanwhile, the average coefficient $M$ values range - 1.43 and 0.68 in regulated sections from different studies. This shows that the sections with a higher value of $M$ (1.43) will be silted and sedimented and intense erosion processes in sections with lower value of the $M$ criterion (0.68) were observed.

This criterion has been tested for different soil conditions by other researchers, and all of them confirmed its reliability (Grinvald et al., 1988; Nikonora et al., 2009, Vaikasas and Ždankus, 2005). Their studies have shown that this stability criterion value varies depending on the river bottom soil, the banks overgrowth and bed meanders’ length. For example, assessing the largest Lithuanian rivers, such as the Nemunas, the Neris, the Sventoji and the Minija its value is $M=0.915$, so the rivers’ state is close to the steady (Vaikasas and Ždankus, 2005). Submountain riverbeds formatted from large rocks are stable and at lower values of $M$ (Grinvalds et al., 1988), and the overgrown banks of the rivers also increase banks stability (Nikonora et al., 2009; Dabrovski et al., 1997; Rimkus et al., 1993). Thus, these studies confirm that the riverbed sediment size and banks overgrowth affect bed processes.

It should be noted that K.V.Grishanin bed stability factor also evaluates the river-bed physical environment balance. Further researches are appropriate to determine the relation between the stability of the bed with living organisms and the influence of habitat formation. Such studies would allow better understanding of the relation between the physical environment of streams and water fauna.

**Conclusions**

According to the stability criterion of K.V.Grishanin it was found that natural rivers (Amarnia, Grūda, Spengla) are close to the natural watercourses with occurring small erosion processes ($M_{awr}=0.87$). Meanwhile, silting and sedimentation processes were determined in the regulated researched stream stretches ($M_{awr}=1.43$).

Comparing results published in the article and results of other researchers it was determined that values of K.V.Grishanin coefficient are ranging in the same range, i.e. $M = 0.81-0.91$. That shows that poor erosional processes are going in the stream beds. The average values of coefficient $M$ were displayed in regulated sections - 1.43 and 0.68, which clearly shows the sedimentation and erosion taking place in the bed processes.

The obtained results compared with other authors’ data confirm the appropriateness of K.V.Grishanin criterion for the assessment of river stability under Lithuanian conditions.

**References**


Raimundas BAUBLYS, Institute of Water Resources Engineering, Faculty of Water and Land Management, Aleksandras Stulginskis University. Address: Universiteto 10, Lt-53361, Akademija, Kauno distr., Lithuania. E-mail address: raimundas.baublys@asu.lt Research interests – investigations of bed processes of natural and regulated rivers.
Elliptical Guide Banks Scour: Equilibrium Stage

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Abstract

The damage of the bridge foundations, in the river flow, because of scour leads to considerable economic and environmental losses. The equilibrium stage of scour near guide banks with a uniform layer and stratified bed conditions have been studied. At present, no methods are available for computing the depth of a local scour near the bridge crossing structures under river bed layering. The aim of this study is to elucidate the influence of scour depth and stratification on the scour depth at elliptical guide banks for clear water conditions on the plain rivers. Scour process is studied according to one of the cases proposed by Ettema (1980), when first layer or next one is fully scoured out.

The depth of scour considerably increases or reduces - depending on grain size of uniform layer and sequence, thickness of layers with different grain sizes. For example, the depth of scour is always greater when a fine-sand layer is under a coarse-sand layer(s) compare with the depth of scour obtained in coarse-sand layer with mean grain size, which is on the top of the river bed. A new method for computing the equilibrium scour depth at elliptical guide banks in uniform and stratified river bed conditions is presented. Equilibrium depth of scour can be calculated by proposed formulas in one or several bed layers with different mean grain size, thickness, and sequence combinations. The method is confirmed by test results. Calculation of the depth of scour at the bridge foundations in the flow and taking into account only the grain size diameter in the upper layer of the river bed, as it expected now, and neglecting stratification will lead to wrong results and finally to considerable damages and losses.

Introduction

Streamline concentration, local increase in velocity, circulation and vortex structures, an increased turbulence, and a scour hole are observed at the head of guide banks. According to different authors, the depth of scour at bridge structures depends on the grain size of the surface layer of the river bed. But this approach does not reflect the complexity of the geological structure of river bed, which can increase the scour depth and cause damage to bridge structures.

The influence of the river bed stratification on the scour depth near bridge structures is confirmed by Rotenburg (1965), Ettema (1980), Raudkivi and Ettema (1983), and the others, but at present time there are no methods or formulas to calculate depth of scour at complex geological river bed conditions.

In this study, a new method for computing the equilibrium depth of scour at elliptical guide banks under uniform and stratified bed conditions is presented. According to experimental and calculation results, the depth of scour in uniform layer depends on grain size and in the stratified bed conditions, the depth of scour depends on the grain size of a layer, as well on thickness and sequence of the layers with different grain size. If the surface layer with a grain size $d_1$ is scoured and the process is continued in the second layer with a grain size $d_2$, where $d_1 < d_2$, the depth of scour is greater in the case of two layers is the same as in one layer with $d_2$. If the surface layer with a grain size $d_1$ is scoured and the process is continued in the second layer with a grain size $d_2$, where $d_1 > d_2$, the depth of scour is greater in the case of two layers is the same as in one layer with $d_2$. If the surface layer with a grain size $d_1$ is scoured and the process is continued in the second layer with a grain size $d_2$, the depth of scour is greater in the case of two layers is the same as in one layer with $d_2$. Equilibrium depth of scour can be calculated by proposed formulas in bed layers with different mean grain size, thickness, and sequence combinations.

Calculation of the depth of scour at the bridge foundations in the flow and taking into account only the grain size diameter in the upper layer of the river bed, as it expected now, and neglecting stratification will lead to wrong results and finally to considerable damages and losses.

Experimental Setup

The tests were carried out in a flume 3.5 m wide and 21 m long. The flow distribution between the channel and the floodplain was studied under open-channel flow conditions (Table 1). The rigid-bed tests were performed for different flow contractions and Froude numbers with the purpose of investigating the changes in velocity and water level near the embankment, along it, and near the modeled elliptical guide bank.

Table 1. Some experimental data for open flow conditions in a flume

<table>
<thead>
<tr>
<th>Test</th>
<th>$L$ (cm)</th>
<th>$h_f$ (cm)</th>
<th>$V$ (cm/s)</th>
<th>$Q$ (l/s)</th>
<th>$Fr$</th>
<th>$Re_f$</th>
<th>$Re_f$</th>
</tr>
</thead>
<tbody>
<tr>
<td>L1</td>
<td>350</td>
<td>7</td>
<td>6.47</td>
<td>16.60</td>
<td>0.0780</td>
<td>7500</td>
<td>4390</td>
</tr>
<tr>
<td>L2</td>
<td>350</td>
<td>7</td>
<td>8.58</td>
<td>22.70</td>
<td>0.10</td>
<td>10010</td>
<td>6060</td>
</tr>
<tr>
<td>L4</td>
<td>350</td>
<td>7</td>
<td>8.16</td>
<td>20.81</td>
<td>0.098</td>
<td>10270</td>
<td>5590/5660</td>
</tr>
<tr>
<td>L5</td>
<td>350</td>
<td>7</td>
<td>9.07</td>
<td>23.48</td>
<td>0.109</td>
<td>11280</td>
<td>6140/6410</td>
</tr>
<tr>
<td>L6</td>
<td>350</td>
<td>13</td>
<td>11.10</td>
<td>28.31</td>
<td>0.134</td>
<td>13800</td>
<td>7550/7840</td>
</tr>
<tr>
<td>L7</td>
<td>350</td>
<td>13</td>
<td>7.51</td>
<td>35.48</td>
<td>0.067</td>
<td>13700</td>
<td>9740</td>
</tr>
<tr>
<td>L8</td>
<td>350</td>
<td>13</td>
<td>8.74</td>
<td>41.38</td>
<td>0.076</td>
<td>16010</td>
<td>11395</td>
</tr>
<tr>
<td>L9</td>
<td>350</td>
<td>13</td>
<td>9.90</td>
<td>47.10</td>
<td>0.088</td>
<td>14300</td>
<td>14300</td>
</tr>
</tbody>
</table>
During sand-bed tests, the time-dependent changes in velocities and scour depth, the effect of different hydraulic parameters, the flow contraction rate, the grain size of bed materials, and the scour process were studied. The tests were performed in a flume of width \( L = 350 \text{cm} \) for the following bridge-model openings: 50, 80, 120, and 200 cm. The flow contraction rate \( Q/Q_b \) (where \( Q \) is the general discharge and \( Q_b \) is the discharge through the bridge opening under open-flow conditions) varied from 1.56 to 5.69 for the floodplain depth \( h_f = 7 \) and 13 cm, respectively; the Froude numbers varied from 0.078 to 0.134; \( Re_c \) – from 7500 to 16010, and \( Re_f \) – from 4390 to 14300, where \( Re_c \) and \( Re_f \) are the Reynolds numbers for the channel and floodplain, respectively; the slope of the flume was 0.0012.

![Figure 1. Geology of the river bed formed by layers with different grain sizes](image)

The sand was placed 1 m up and down the contraction point of the flume. The grain sizes were 0.24 and 0.67 mm, and the tests were performed with a uniform layer or with two layers of different thicknesses and grain sizes. The dimension of the upper part of an elliptical guide bank, namely the length calculated according to the Latischenkov (1960) method and was found to be dependent on the flow contraction rate and the main channel width. The length of the lower part of the guide bank was assumed to be half of the upper part.

Scour process is studied according to one of the cases proposed by Ettema (1980), when first layer or next one is fully scoured out, and scour continue to develop in the next layer due to the new hydraulic conditions (Fig.2).

![Figure 2. Scour in layered river bed, Case 11 (after Breusers and Raudkivi, 1991)](image)

### Equilibrium depth of scour at uniform layer elliptical guide banks

The scour depth at elliptical guide banks is equal to the equilibrium depth in the conditions when the local velocity becomes equal to the critical one. The local velocity at a plain river bed is found by the Bernoulli equation for two cross sections of the extreme unit streamline \([Gjunsburgs and Neilands, 2004]\). The discharge across the width of a scour hole before and after the development of scour is \( Q_f = Q_{se} \), where \( Q_f \) is the discharge across the width of a scour hole with the plain bed and \( Q_{se} \) is that with a depth \( h_{equil} \):

\[
m \cdot h_{equil} \cdot h_f \cdot V_{lel} = \left[ m \cdot h_{equil} h_f \cdot \frac{m \cdot h_{equil}}{2} \right] V_{lt}
\]

where \( m \) is the steepness of the scour hole, \( h_{equil} \) is the depth of scour at the equilibrium stage, \( h_f \) is the depth of flow at the floodplain, \( V_{lel} \) is the local velocity at plain river bed, and \( V_{lt} \) is local velocity at any depth of scour \([Gjunsburgs et al., 2006]\). The local velocity \( V_{lt} \) at an equilibrium stage of scour is determined from Eq. (1)
The critical velocity \( V_{lt} \) at the equilibrium stage can be determined through the mean depth of flow \( h_m = h_f(1+h_{equil}/2h_f) \) near elliptical guide banks at that stage:

\[
V_{lt} = \frac{V_{lel}}{1 + \frac{h_{equil}}{2h_f}}
\]

(2)

where \( \beta \) is a coefficient of reduction in the critical velocity due to vortex structures, \( d_i \) is the grain size of the bed materials, and \( V_0 = 3.6d_i^{0.25}h_f^{0.25} \) is the critical velocity at the plain bed (Studenichnikov 1964).

The scour at the equilibrium stage stops when the local velocity \( V_{lt} \) (Eq. 2) becomes equal to the critical velocity \( V_{0t} \) (Eq. 3):

\[
V_{lt} = \frac{V_{lel}}{1 + \frac{h_{equil}}{2h_f}} = \beta \cdot 3.6d_i^{0.25}h_f^{0.25} \left[ 1 + \frac{h_{equil}}{2h_f} \right]^{0.25}
\]

(3)

Equilibrium depth of scour at stratified bed at elliptical guide banks

Geology of the river bed is complicate and usually has layers with different thickness and grain sizes (Fig. 3).

Figure 3. Two layers with different test grain sizes

When the scour depth \( h_{equil} < H_{d1} \), equation (5) can be used; however, when \( h_{equil} > H_{d1} \), the scour develops in the second layer with a grain size \( d_2 \). If \( h_{equil} > H_{d1} + H_{d2} \), the scour develops in the third layer with a grain size \( d_3 \), and so on. Then, the equilibrium scour depth is different from that in the uniform layer. At the initial stage, the equilibrium scour depth \( h_{equil} \) is calculated by Eq. (5). When \( h_{equil} > H_{d1} \), the scour develops in the second layer with \( d_2 \). Now, to determine the equilibrium depth of scour the local and critical velocities on the top of the second layer must be calculated. The local velocity on the surface of the second layer is found by the formula

\[
V_{lt1} = \frac{V_{lel}}{1 + \frac{H_{d1}}{2h_f}}
\]

(6)

where \( H_{d1} \) is the thickness of the first layer of the river bed.

The critical velocity is determined from the medium depth of flow \( h_m = h_f(1+h_{equil}/2h_f) \) on the floodplain with a scour depth equal to the thickness of the first bed layer,

\[
V_{01} = \beta 3.6 \cdot d_2^{0.25} h_f^{0.25} \left[ 1 + \frac{H_{d1}}{2h_f} \right]^{0.25}
\]

(7)

where \( V_0 = 3.6d_i^{0.25}h_f^{0.25} \) is the critical velocity of flow for the grain size \( d_2 \), since the layer with exactly this diameter lies on the top of the river bed. Then, the scour depth in the second layer is determined as
\[
    h_{s2} = 2h_f \left[ \frac{V_{hf}}{V_{01}} \right]^{0.8} - 1 \cdot k_{\alpha} \cdot k_m
\]

(8)

At \( h_{s2} < H_{d2} \), the scour stops, and the equilibrium scour depth is

\[
    h_{equl} = H_{d1} + h_{s2}
\]

(9)

If \( h_{s2} > H_{d2} \), the calculation could be continued using Eq. (8).

Results

The flow pattern at the head of the elliptical guide banks is modified. As it was found in the tests, the streamlines are bended, flow velocities reduce almost to zero when flow approaching the bridge crossing embankments and then gradually increases. At the head of the elliptical guide banks the concentration of streamlines, a sharp drop in water level, a local increase in the velocity, and circulation was observed (Gjunsburgs et al. 2004). Locally modified flow near the guide banks is forming the local scour hole.

The local velocity \( V_h \) reduces more rapidly if the second layer has grains of a smaller size. Depending on the layers grain size, the critical velocity \( \beta V_0 \) either increases, when the grains of the second layer are coarser, or reduces, when these grains of the second layer are finer.

The test results are presented in Table 2. The EL4-6 tests were performed with one uniform layer with a mean diameter of 0.24 mm, the EL16-18 tests with a mean diameter of 0.67 mm, and the EUL 1-6 tests were carried out with two layers of different thickness with grain sizes \( d_1 = 0.24 \) mm and \( d_2 = 0.67 \) mm.

Table 2. Test results for elliptical guide banks

<table>
<thead>
<tr>
<th>Test</th>
<th>( \frac{Q}{Q_b} )</th>
<th>( d_1 ) (mm)</th>
<th>( d_2 ) (mm)</th>
<th>( H_{d1} ) (cm)</th>
<th>( H_{d2} ) (cm)</th>
<th>( t ) (h)</th>
<th>( h_{s1} ) calc (cm)</th>
<th>( h_{s2} ) test (cm)</th>
<th>( \frac{h_{s1}}{h_{s calc}} )</th>
<th>( h_{equl} ) (cm)</th>
<th>( h_{equl} ) (cm)</th>
<th>( h_{equl} ) (layers) (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>EL4</td>
<td>3.66</td>
<td>0.24</td>
<td>-</td>
<td>50</td>
<td>-</td>
<td>7</td>
<td>7.6</td>
<td>8.40</td>
<td>0.905</td>
<td>10.43</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>EL5</td>
<td>3.87</td>
<td>0.24</td>
<td>-</td>
<td>50</td>
<td>-</td>
<td>7</td>
<td>11.0</td>
<td>11.00</td>
<td>1.000</td>
<td>14.10</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>EL6</td>
<td>3.78</td>
<td>0.24</td>
<td>-</td>
<td>50</td>
<td>-</td>
<td>7</td>
<td>14.0</td>
<td>13.51</td>
<td>1.036</td>
<td>17.65</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>EL16</td>
<td>3.78</td>
<td>0.67</td>
<td>-</td>
<td>50</td>
<td>-</td>
<td>7</td>
<td>6.1</td>
<td>5.60</td>
<td>1.084</td>
<td>9.00</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>EL17</td>
<td>3.87</td>
<td>0.67</td>
<td>-</td>
<td>50</td>
<td>-</td>
<td>7</td>
<td>8.4</td>
<td>8.35</td>
<td>1.005</td>
<td>8.91</td>
<td>14.10</td>
<td>14.10</td>
</tr>
<tr>
<td>EL18</td>
<td>3.78</td>
<td>0.67</td>
<td>-</td>
<td>50</td>
<td>-</td>
<td>7</td>
<td>12.2</td>
<td>10.50</td>
<td>1.162</td>
<td>11.78</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>EUL1</td>
<td>3.66</td>
<td>0.67</td>
<td>0.24</td>
<td>4</td>
<td>46</td>
<td>7</td>
<td>8.2</td>
<td>8.48</td>
<td>0.966</td>
<td>5.90</td>
<td>10.43</td>
<td>10.43</td>
</tr>
<tr>
<td>EUL2</td>
<td>3.87</td>
<td>0.67</td>
<td>0.24</td>
<td>7</td>
<td>43</td>
<td>7</td>
<td>10.7</td>
<td>10.85</td>
<td>0.986</td>
<td>8.91</td>
<td>14.10</td>
<td>14.10</td>
</tr>
<tr>
<td>EUL3</td>
<td>3.78</td>
<td>0.67</td>
<td>0.24</td>
<td>10</td>
<td>40</td>
<td>7</td>
<td>12.4</td>
<td>11.97</td>
<td>1.035</td>
<td>11.78</td>
<td>17.65</td>
<td>17.65</td>
</tr>
<tr>
<td>EUL4</td>
<td>3.66</td>
<td>0.24</td>
<td>0.67</td>
<td>4</td>
<td>46</td>
<td>7</td>
<td>5.6</td>
<td>5.74</td>
<td>0.975</td>
<td>10.43</td>
<td>5.90</td>
<td>5.90</td>
</tr>
<tr>
<td>EUL5</td>
<td>3.87</td>
<td>0.24</td>
<td>0.67</td>
<td>7</td>
<td>43</td>
<td>7</td>
<td>8.6</td>
<td>8.44</td>
<td>1.018</td>
<td>14.10</td>
<td>8.91</td>
<td>8.91</td>
</tr>
<tr>
<td>EUL6</td>
<td>3.78</td>
<td>0.24</td>
<td>0.67</td>
<td>10</td>
<td>40</td>
<td>7</td>
<td>11.4</td>
<td>11.03</td>
<td>1.033</td>
<td>17.62</td>
<td>11.78</td>
<td>11.78</td>
</tr>
</tbody>
</table>

The opening of the bridge model was 80 cm and the floodplain depth was 7 cm. The tests lasted for 7 hours. The scour depth developed in 7 hours was prolonged to an equilibrium stage by using the method elaborated by Gjunsburgs et al. (2007). The equilibrium scour depth in tests with uniform layer was respectively 10.43, 14.10, and 17.65 cm with mean grain-size diameters 0.24 mm and 5.90 cm and 8.91 cm and 11.78 cm with a 0.67 mm diameter. The Froude numbers of the open flow were 0.078, 0.104, and 0.124. The tests with two layers were performed for different thicknesses and grain sizes of layers. In the EUL1, EUL2, and EUL3 tests, the first and the second layers had grain sizes of 0.67 and 0.24 mm, respectively. When the layer was scored and \( h_s > H_{d2} \), the second layer had the grain size, and the next layer gave smaller values. In the EUL4, EUL5, and EUL6 tests, the first layer had the grain size \( d_1 = 0.24 \) mm on the surface. As follows from experimental results and the method presented, the dominant grain size for calculating the depth of scour at elliptical guide banks under stratified bed conditions is the mean diameter of the second layer or of any next layer where the scour stops.
Dependence on the sequence of layers, ratio of velocities, the Froude numbers of the open flow, \( Fr \), the Froude number with a local velocity at the head of elliptical guide banks, \( Fr_{vl} \), the Froude number at the end of the tests, with a depth of scour \( h_s \), \( Fr_{vl} \), the densimetric Froude number, and the densimetric Froude number at the guide banks with a local velocity, \( Fr_{d1} \), on relative depth of scour is found.

The equilibrium depth of scour is always greater if the coarse-grain layer lies on the top of the river bed and a fine-grain layer goes after it, and the depth is smaller if the fine-grain layer lies on the surface of the river bed.

**Conclusions**

The equilibrium stage of scour at guide banks under uniform and stratified bed conditions have been studied. The method for computing the equilibrium depth of scour under these conditions is presented (Eq. 8). The method is confirmed by test results (Table 1). According to the method and test results, the equilibrium depth of scour at elliptical guide banks strictly depends on the sequence of the bed layers with different grain sizes. When the first uniform coarse sand layer is scoured \( h_s > H_{d1} \) (Fig. 2), the equilibrium depth of scour becomes equal to its value achieved in the second uniform fine sand layer with a grain size \( d_2 \). If the first fine sand layer is scoured (Fig. 2), the equilibrium scour depth is equal to that in the second coarse sand layer (Table 1). In the stratified bed conditions, the use of grain-size parameters of the river bed material on the surface for calculating the equilibrium scour depth yields incorrect results. The most critical conditions for structures appear when a fine-sand layer occurs under a coarse-sand layer. As soon as the coarse layer has been scoured out, the scour is rapidly developing in the next, fine-sand one. In this case, the dominant value of grain size for computing the depth of scour at elliptical guide banks under stratified bed conditions is the mean diameter of the second layer or of the next one, where the scour stops. According to the results, the depth of scour is always greater when a fine-sand layer is under a coarse-sand layer(s) compare with the depth of scour obtained with mean grain size which is on the top of the river bed. The calculation of scour depth near bridge structures in flow by using only the mean grain size diameter on top of the river bed and neglecting the stratification ,as it excepted now, can lead to wrong results and finally to considerable damages and losses.

**References**


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Phosphorus and Potassium Migration in Different Crop Rotations

Saulius Gužys
Aleksadras Stalgalinskis University, Lithuania

Abstract

The investigations were carried out during 2006-2011 in the land of the Water resources engineering institute of ASU, in village of Lipštėnai on Endocalcari Endohypogleic Cambisol (CMg-n-w-can). The base of investigations is 3 drainage systems, which contain cereals differing in fertilization and grasses crop rotations. The aim of investigations is to determine the crop rotations differing in fertilization and this relations with cycles of phosphorus and potassium in agroecosystem.

Higher productive was perennial grasses crop rotation. In the conditions of cereal crop rotations this productive was 3-46% lesser. The highest concentration of P-PO$_4^{3-}$ in drainage water was received in the conditions of higher fertilization cereals crop rotation while highest concentration of total P and K$^+$ in the conditions of grasses crop rotation. The highest leaching of P-PO$_4^{3-}$ and total P by drainage was received under the conditions of higher fertilization cereals crop rotation. The highest leaching of K$^+$ was received under the conditions of grasses crop rotation. The leaching of P-PO$_4^{3-}$ and potassium essentially depends on fertilization, drainage runoff as well as cumulative and yearly balance of P and K.

The application of all crop rotations was distinguished by positive P balance. Cumulative balance of potassium under the conditions of higher fertilization cereal crop rotation was moderate negative. The highest deficit of cumulative potassium balance was received under the conditions of grasses crop rotation. The aim of our investigations is to estimate of dependence of migration phosphorus and potassium on environmental factors.

Key words: phosphorus, potassium, yield, concentration, leaching, balance.

Introduction

Phosphorus is one of the key elements necessary for all living organisms. Lithuanian soils have very little labile phosphorus. Without additional fertilization, soil phosphorus reserves could yield grain harvest only 2.0 t/ha. And the lowest level of phosphorus content in soil, compensated by the decay process, is 20-50 mg kg P$_2$O$_5$ (Mattson, 1998; Loes et al., 2001).

Phosphorus utilization review in agriculture of advanced countries has highlighted two main problems:

1. Accumulation of phosphorus in soil due to fertilization to a level exceeding agricultural plants needs.
2. Phosphorus migration from the system "soil - plant" and its accumulation in surface water bodies (Some phosphorus..., 1998; Delgado and Scalenghe 2008).

Recycling of phosphorus in agroecosystem in many countries is similar. Specialized farms, using mineral and organic fertilizers, destroy the natural cycles of phosphorus, phosphoric ingress is higher than taking from a field with vegetative yield, therefore this element is accumulated in soil (Sharpley et al., 1998; Sharphey et al., 2001; Mattson, 1998; Heckrath et al., 1997).

Although some authors (Some phosphorus..., 1998; Bunemann et al, 2005) suggest that additional phosphorus in fertilizers is not mobile and within 24 years all of it remains in the upper (0-25 cm) soil layer. Many other researchers indicate that in the regions with increased phosphorus content P washing-off with surface water and leaching of with drainage increase, stimulating eutrophication of water bodies (Sharprey et al., 1998; Sims, 1998; Geohring et al., 2001; Hooda et al., 1999; Šileika et al., 2000; Bučienė, Lundenkvam, 1997). Canadian studies have shown that the risk of P accumulation on soil surface is higher in clay soils, moderately provided with phosphorus. Sweden researchers found that leaching of P with drainage be less than 2 kg ha$^{-1}$, if labile P$_2$O$_5$ in soil was more than 150 mg kg$^{-1}$. Any phosphorus augmentation in soil proportionally increased its concentration in drainage water.

There almost no studies evaluating migration of phosphorus compounds through various lands use (nonarable farming keeping constantly occupied land). Norway researchers found that the highest P losses occur during the autumn plowing. When growing winter plants, P losses go down. Leaching of P also increases applying higher than reasonable fertilizing (Lundenkvam, 1998).

The country has 21 percent of soils with very low and low potassium content, 37 percent of average, and 42 percent - of sufficient potassium content. Most of very low and low-potassium soils or in the West (25 percent) and in the East of the country (22 percent), a bit lesser - in Central Lithuania (17 percent). (Mažvilė, Adomaitis, 2005). Since many Lithuanian soils have low potassium content, in order to increase potassium content in them, the balance intensity should be around 120-150 per cent (Mašauskas et al., 2000). Potassium reserves in soil are replenished by fertilization. It was pointed out that without fertilizing, labile phosphorus content in the soils rich with potassium would be enough only to grow 1.9 to 2.0 t ha$^{-1}$ of the crop of corn. Influence of fertilization systems on soil properties and output yield was rather extensively studied in Lithuania and abroad. According to most researchers, fertilizing systems efficiency increases in the following order: unfertilized – manure – NPK (Nitrogen, Phosphorous, Potassium) – manure + NPK (Bagdonienė, 1996). It is believed that the organic and mineral fertilizers are equivalent in relation to K nutrition (Kulakovskaya, 1978). Fertilizers potassium in soil is rapidly sorbed; therefore it has low migration. When higher rates of potassium are brought into soil, potassium fixation in moist soils decreases, and in the dry soils - increases (Sardi, Csitari, 1998). Some authors indicate that migration of potassium in soil profile is determined by its geochemical surrounding, organic substances synthesis and reaction. Potassium in neutral and limed soils has higher stability, while in the acid soils it is quickly washed out (Knašys, 1985). It is also stated that in sandy soils potassium is sorbed quite a little and the losses from leaching are large (Askegaard et. al, 2003). In addition it is noted that apart from soil and meteorological conditions, potassium migration is affected by cultivated plants and fertilization. Higher potassium...
migration occurs when applying fallow and cereal monoculture. But applying potassium rich crop rotations, accumulating more biomass (potatoes, beets, grass) reduces potassium migration (Yalaranta et al., 1996; Tyla et al., 1997). It is noted that exchange potassium is the main instrument regulating leaching of potassium by drainage and in the autumn exchange potassium should not exceed 30 mg per soil kg. This can be achieved by properly adjusting the crop rotation, using cereal straw as fertilizer (Askegaard et. al., 2003).

The aim of our investigations is to estimate of dependence of migration phosphorus and potassium on environmental factors.

Materials and methods

The study was carried out in 2006-2011 in the Central Lithuanian Lowland, on the land of Water Resources Engineering Institute, Faculty of Land and Water Management at Aleksandras Stulginskis University, in the village of Lipliūnai. The basis of the study is three drainage systems (12-16 ha), in each of them a separate, differently fertilized rotation of field plants was used (Table 1).

Table 1. Field plant rotations and fertilization with phosphorus and potassium (kg of active material ha⁻¹)

<table>
<thead>
<tr>
<th>Crop rotation</th>
<th>Reduced fertilization of cereals</th>
<th>Increased fertilization of cereals</th>
<th>Perennial grasses</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>P₂₀₆K₂₁₄</td>
<td>P₁₄₅K₆₀₂</td>
<td>P₁₅₆K₂₀₁</td>
</tr>
</tbody>
</table>

The plants were fertilized only with mineral fertilizers. The research ground is for production needs, therefore the amount of fertilizer used for each rotation was limited by financial capabilities of the farm.

The soil - Endocalcari Endohypogleyic Cambisols. According to the granulometric composition the test area's soil is sandy loam on sand. Before testing the soil had neutral reaction (pH KCl 7.1 to 7.2), phosphorus and very rich in phosphorus (158-232 mg kg⁻¹, P₂O₅), and with low and medium potassium content (62-114 mg kg⁻¹ K₂O). Humus and total nitrogen content ranged from 1.6 to 4.4 and from 0.07 to 0.3%. For determination of soil agrochemical characteristics the samples were taken in the autumn, after the harvest by drilling to the depth of 60 cm or less, in every 20 cm in accordance with the horizons. In each variant three combined samples were taken from 15-20 wells.

Drainage water runoff was measured by volumetric method every 3 days. Its samples, when run-off occurred, were taken every 10 days. P-PO₄³⁻ concentration in water was determined with colorimetric method, K⁺ - with a spectrophotometer (Unifikuoti nuotekų... 1999). Soil analyzes were conducted with the following methods: humus - with Tyurin method, labile P₂O₅ and K₂O - with AL method, total N - with Kjeldahl method (Fomin et al. 2000). The area of recorded cereal and grass crop fields - 30 m², of accumulation fields - 45 m². Total energy yield is calculated based on the literature (Jankauskas et al., 2000). In plant produce PK content is determined from 1 extract by combustion with concentrated H₂SO₄, hydrogen peroxide and a Se catalyst. The data were processed by the methods of mathematical statistics. Variance and correlation-regression analysis methods were applied. The errors for each variant were calculated separately (Dyke, 1994). * - reliable at 95, ** reliable at 99% probability levels.

Results and discussion

The studies of field plants yield of different rotations (Table 2) showed that in most cases the highest productivity was in higher fertilization and grasses rotations. During the six years of research the rotation with higher cereal fertilization has accumulated yield of 974, and that of grasses - 1009 GJ ha⁻¹ of total energy. And it is 77 and 84% compared with the least fertile Combine lower fertilization rotation. Average concentrations of phosphorus and potassium and of their compounds in drainage water (Table 3) showed a small difference in P-PO₄³⁻ using different rotations. Only when applying crop rotation of higher fertilization, it somewhat increases (33%) to 0.008 mg l⁻¹. Meanwhile, the highest concentration of total phosphorus was received in applying grass rotation - up to 0.021 mg l⁻¹.

And it is 31% higher than when applying lower fertilization of cereal rotations and 10% higher than applying higher fertilization. The highest K⁺ concentration in drainage water was also obtained in applying grass rotation. This is explained by the fact that the grass roots are able to break up minerals hardly assimilated by plants, at the same time enriching soil with mobile compounds. The lowest potassium concentration was in crop rotation with increased fertilization.

Table 2. Average total energy yield of field crops GJ ha⁻¹ (main and secondary produce)

<table>
<thead>
<tr>
<th>Crop rotation</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>Sum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower cereal fertilization</td>
<td>62</td>
<td>79</td>
<td>126</td>
<td>93</td>
<td>80</td>
<td>109</td>
<td>549</td>
</tr>
<tr>
<td>Higher cereal fertilization</td>
<td>62</td>
<td>310</td>
<td>145</td>
<td>103</td>
<td>160</td>
<td>194</td>
<td>974</td>
</tr>
<tr>
<td>Grasses</td>
<td>253</td>
<td>103</td>
<td>258</td>
<td>234</td>
<td>67</td>
<td>94</td>
<td>1009</td>
</tr>
</tbody>
</table>
The data of total phosphorus and potassium compounds leaching showed (Table 4) that most of all phosphates and overall potassium were washed when applying crop rotation with higher fertilization. Compared to grass rotation, leaching of phosphates was 59% higher, and of total phosphorus - 23% higher. Leaching of potassium compounds, applying cereal and grass rotations with lower fertilization, differed only a little. Meanwhile, the highest leaching of potassium by drainage is found in the conditions of perennial grass crop rotation (3.15 kg ha\(^{-1}\)).This is related to the ability of the roots of potassium-loving perennial grasses to break up hard-soluble minerals and enrich soil with labile K compounds. A little lower leaching (4%) was under the conditions of crop rotation with lower fertilizing. The lowest leaching during the 6 years of study was found under the conditions of crop rotation with higher fertilizing (2.34 kg ha\(^{-1}\)).This is related to the greater yield here and its preventive effect of leaching.

Table 3. Influence of different crop rotations to the average annual phosphorus and potassium concentrations in drainage water, mg l\(^{-1}\)

<table>
<thead>
<tr>
<th>Crop rotation</th>
<th>P-PO(_4)</th>
<th>Total P</th>
<th>K(^+)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower cereal fertilization</td>
<td>0.006</td>
<td>0.016</td>
<td>0.83</td>
</tr>
<tr>
<td>Higher cereal fertilization</td>
<td>0.008</td>
<td>0.019</td>
<td>0.62</td>
</tr>
<tr>
<td>Grasses</td>
<td>0.006</td>
<td>0.021</td>
<td>0.94</td>
</tr>
<tr>
<td>LSD(_{0.05})</td>
<td>0.003</td>
<td>0.007</td>
<td>0.16</td>
</tr>
</tbody>
</table>

Table 4. The influence of different crop rotations on the total leaching of phosphorus and potassium by drainage, kg ha\(^{-1}\)

<table>
<thead>
<tr>
<th>Crop rotation</th>
<th>P-PO(_4)</th>
<th>Total P</th>
<th>K(^+)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower cereal fertilization</td>
<td>0.015</td>
<td>0.057</td>
<td>3.02</td>
</tr>
<tr>
<td>Higher cereal fertilization</td>
<td>0.027</td>
<td>0.070</td>
<td>2.34</td>
</tr>
<tr>
<td>Grasses</td>
<td>0.017</td>
<td>0.057</td>
<td>3.15</td>
</tr>
<tr>
<td>LSD(_{0.05})</td>
<td>0.008</td>
<td>0.01</td>
<td>1.12</td>
</tr>
</tbody>
</table>

The performed correlation-regression analysis of dependence of phosphates phosphorus leaching on environmental factors (Table 5) showed that it mainly depended on fertilization with phosphorus fertilizers, drainage runoff, annual and cumulative phosphorus balance of the agroecosystem. Unlike with P-PO\(_4\)\(^{-3}\) concentrations in drainage water, phosphorus content in soil and agroecosystem fertility had no effect on phosphorus leaching. In this way, P-PO\(_4\)\(^{-3}\) leaching under the influence of fertilizing with phosphorus fertilizers changes parabolically and the minimum is obtained with fertilization up to 42 kg of active material ha\(^{-1}\). On further increasing fertilization phosphate leaching is growing. Under the influence of annual drainage runoff and annual P balance, phosphate leaching varies in straight-line regularity and increases when these parameters increase. Whereas under the influence of cumulative phosphorus balance, phosphates leaching by drainage changes parabolically and the lowest is when agroecosystem's P balance is low (+8 kg ha\(^{-1}\)). More redundant P balance increases P-PO\(_4\)\(^{-3}\) leaching by drainage.

The correlation - regression analysis of potassium leaching showed that K leaching by drainage mainly was associated with agroecosystem fertilization with potassium fertilizers, drainage runoff, the annual and cumulative potassium balance of the agroecosystem (Table 5). Under the influence of fertilization with potassium fertilizers, K\(^+\) leaching by drainage changes parabolically and decreases when fertilization is in excess of 22 kg of active material ha\(^{-1}\). This is probably due to higher fertility of the agroecosystem. Under the influence of annual drainage runoff, potassium leaching changer in straight-line regularity. The lowest potassium leaching by drainage is obtained at low positive (+9 kg ha\(^{-1}\)) potassium balance of the agroecosystem. A higher redundant potassium balance increases its leaching. Phosphorus balance studies showed that when applying grass rotation it almost always was slightly positive, and after 6 years of research was +35.0 kg ha\(^{-1}\) (Table 6). Much more redundant it was under the conditions of crop rotation with lower fertilization. The highest surplus phosphorus balance was in the crop rotation with higher fertilization, where after 6 years of study its surplus was 274.2 kg ha\(^{-1}\).

The studies of potassium balance have shown somewhat different results. With slightly or moderately negative potassium balance during all the years of research, crop rotation with higher fertilization after six years of research had balance deficit of only -1.6 kg ha\(^{-1}\). The redundant potassium balance during all years of research was in crop rotation with lower fertilization, where after 6 years of study its cumulative surplus was +137.9 kg ha\(^{-1}\). Meanwhile unfertilized grass rotation showed a very high K balance deficit, which, after six years of research was as high as -448.3 kg ha\(^{-1}\).
Table 6. Influence of different crop rotations on cumulative phosphorus and potassium balance

<table>
<thead>
<tr>
<th>Crop rotation</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>Sum 2006-2011</th>
</tr>
</thead>
<tbody>
<tr>
<td>P balance</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cereals, lesser fertilization</td>
<td>18.7</td>
<td>43.9</td>
<td>55.6</td>
<td>76.6</td>
<td>104.3</td>
<td>142.3</td>
</tr>
<tr>
<td>Cereals, higher fertilization</td>
<td>34.7</td>
<td>88.0</td>
<td>121.4</td>
<td>177.6</td>
<td>223.2</td>
<td>274.2</td>
</tr>
<tr>
<td>Grasses</td>
<td>32.4</td>
<td>46.5</td>
<td>19.2</td>
<td>-5.4</td>
<td>-8.0</td>
<td>35.0</td>
</tr>
<tr>
<td>K balance</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
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<td>35.1</td>
<td>73.4</td>
<td>70.9</td>
<td>93.3</td>
<td>107.1</td>
<td>137.9</td>
</tr>
<tr>
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<td>-121.9</td>
<td>-59.9</td>
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<td>-1.6</td>
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<tr>
<td>Grasses</td>
<td>5.2</td>
<td>15.1</td>
<td>-299.8</td>
<td>-452.3</td>
<td>-490.8</td>
<td>-448.3</td>
</tr>
</tbody>
</table>

Conclusions

The research of different crop rotations in Endocalcari Endohypogleyic Cambisols, slightly loamy soil (RDg4-K2), carried out in 2006-2011 at Aleksandras Stulginskis University allows making fundamental assumptions and generalizations:

1. The highest total output yield of field plants was in perennial grass rotation with minimum fertilization (1009 GJ ha⁻¹). The output yield of crop rotations with higher and lower fertilization was respectively 3 and 46% lower.
2. The highest concentration of phosphates phosphorus in drainage water was obtained from application crop rotations with higher fertilization and the highest total P and K⁺ concentrations - using grass rotation, 0.008, 0.021 and 0.94 mg l⁻¹, respectively. When applying grass rotations with lower fertilization and almost unfertilized grass rotations, P-PO₄ concentrations in drainage water decrease 25% - up to 0.006 mg l⁻¹. Whereas potassium concentration on applying crop rotations with higher and lower fertilization was reduced by 34 and 12% - to 0.62 and 0.83 mg l⁻¹.
3. The largest phosphates and total phosphorus leaching by drainage was obtained from application of abundantly fertilized crop rotation (0.027 and 0.07 kg ha⁻¹). Meanwhile, the highest leaching of potassium was obtained from applying grass rotation (3.15 kg ha⁻¹).
4. Leaching of phosphates phosphorus and potassium by drainage mostly depended on fertilizing with P and K fertilizers, drainage runoff, annual and cumulative P and K balance.
5. All the crop rotations had a positive cumulative P balance. After 6 years of research the grass rotations has showed a little positive balance of P (35.0 kg ha⁻¹) while the most abundant cumulative surplus has been in the crop rotation with higher fertilization (274.2 kg ha⁻¹).
6. The cumulative balance of potassium applying crop rotation with higher fertilization was a little negative (-1.6 kg ha⁻¹). More redundant it was on applying crop rotations with lower fertilization. Very large deficit of K balance was in grass rotation with minimum fertilization (-448.3 kg ha⁻¹).

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The Contribution of the Natural Environment to Sustainable Development on the Example of Rural Areas in the Region of Warmia and Mazury

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Abstract

The natural environment is an element of sustainable development which affects social and economic growth. High nature value is a factor that often contributes to conflict between users of space. In the process of social and economic development, efforts should be made to prevent the degradation of the natural environment. Environmental threats could pose a major obstacle to sustainable development. The potential of the natural environment has to be identified before the implementation of effective conservation measures. This paper characterizes the potential of agriculture and tourism as the main economic drivers in the Region of Warmia and Mazury which rely on the natural environment in line with the principles of sustainability. The main source of information for this analysis was the data supplied by the Central Statistical Office in Poland. The region's environmental potential was evaluated in view of natural features that contribute to the development of agriculture and tourism. Selected indicators of environmental potential were determined separately for agriculture and tourism. The indicators were normalized and expressed numerically for a separate comparison of agriculture and tourism functions. The synthetic Perkal index was applied to the analyzed features to evaluate the environmental potential of each function separately. The resulting numerical values of each function were compared to determine the environmental potential of each municipality. In the last stage of the process, the results of the analysis were compared with the strategic development goals in the Region of Warmia and Mazury.

Introduction

Under the provisions of art. 30, point 50 of the Environmental Protection Law (Ustawa Prawo ochrony środowiska, 2001, No. 62, item 627), sustainable development is defined as a process of social and economic growth which integrates political, economic and social measures, in observance of equilibrium throughout the natural world and the permanence of basic natural processes, to cater to the basic needs of local communities and individuals of the present and future generations. Economic functions should be regarded as integrated forms of human activity which are dependent on the natural environment on the assumption they do not pose a threat to the quality and stability of natural resources. Regions with a predominance of areas of outstanding natural value are often faced with the problem of conflicting planning functions in rural areas. For this reason, social and economic growth processes should be managed in a way which prevents the degradation of the natural environment. The Region of Warmia and Mazury is situated in north-eastern Poland, and it is an area of high natural value. The main drivers of the local economy are agriculture, tourism, forestry and industrial processing involving environmentally-friendly technologies. The natural environment has to be identified before the implementation of effective conservation measures. Threats to the natural environment can hinder sustainable development in the region. This paper characterizes the potential of natural environment for the development of agriculture and tourism as the main economic drivers in the Region of Warmia and Mazury. The region's environmental potential was evaluated in view of natural features which contribute to the development of agriculture and tourism. Selected indicators of environmental potential were determined separately for agriculture and tourism. The indicators were normalized and expressed numerically for a separate comparison of agriculture and tourism functions. The synthetic Perkal index was applied to the analyzed features to evaluate the environmental potential of each function separately. The resulting numerical values of each function were compared to determine the environmental potential of each municipality. In the last stage of the process, the results of the analysis were compared with the strategic development goals in the Region of Warmia and Mazury.

Natural characteristics of the Region of Warmia and Mazury

The Region of Warmia and Mazury is situated in north-eastern Poland between the Vistula River valley and the Neman River valley. The region is characterized by a high degree of naturalness with diverse relief, abundance of lakes, extensive forests, rich flora and fauna. With the exception of one constituent municipality, the Region of Warmia and Mazury is part of the area referred to as the “Green Lungs” of Poland which covers the most attractive natural sites in the country.

The Region of Warmia and Mazury has a highly diverse relief which was formed during the last glacial period. The north-western parts of the region are intersected by rivers Pasłęka and Łyna and their tributaries which create valleys with steep fluvial terraces. The northern part of the region has a nearly plain landform with an abundance of forests and heaths. Dense forest complexes, including the Piska Forest and Napiwodżko-Ramuckie Forest, are intersected by wide and swampy valleys of River Narew’s tributaries. Lakes are the most characteristic feature of Warmia and Mazury, in particular its central-eastern parts. The highest number of lakes is noted in lake belts and the Land of the Great Masurian Lakes. The region has an abundance of natural water trails and lakes, and it is regarded as one of the most scenic areas in Poland. Surface waters cover an area of 151,644 ha, which accounts for 6.3% of the region's territory. The largest lakes are Sniardwy, Mamry and Nieogocin. The region also features two waterway systems connecting lakes: the Great Masurian Lake system connecting lakes Sniardwy, Mikołajskie, Talty, Nieogocin and canals with Lake Mamry, and the Warmia Lake system connecting lakes Drużno, Piniewo, Samobród, Ruda Woda, Hłusk, 266
Drwęckie and others. The latter includes the Ostróda-Elbląg Canal connecting several smaller waterways (Gwiaździńska, 2004).

Forests significantly contribute to the scenic beauty of the Region of Warmia and Mazury. They occupy around 30.9% of the region's area and are situated mainly in its southern part which is characterized by unfertile soils. Forests were the region's primeval flora which had a 80% share of the territory in the 13th century. They comprised mainly mixed forests of pedunculate oaks, common hornbeams, small-leaved limes and field elms. Black alder and common ash were the main species in wetlands, whereas light soil habitats were dominated by pines with a higher than present participation of deciduous trees. Forest complexes such as Romnicka, Borecka, Piska, Napiwodzko-Ramuckie, Taborskie, Iławskie and Kadyńskie are remnants of the region's primeval flora. Bogs are also a characteristic feature of the Region of Warmia and Mazury, and they are found mainly in southern and south-eastern parts of the region as well as in the Land of the Great Masurian Lakes. The region's transitional flora is composed of species typical of Central, Western and Northern Europe as well as the Baltic States. The local fauna is also characterized by significant diversity.

The climate of the Region of Warmia and Mazury is closely correlated with its geographic location and the combined effects of continental and maritime climates. The local landform, including numerous hills, an abundance of lakes and the proximity of the Baltic, also contribute to climate variation. Warmia and Mazury is the second coldest Polish region after mountainous areas in the south, and it is characterized by high variability and a short growing period (Gwiaździńska, 2004).

Soil conditions are an important natural factor which affects regional development. The predominant soil material in the region is boulder clay which was formed beneath ice sheets and glaciers. Clay comprises surface and shallow soil horizons in many parts of the region. The most fertile soils in Warmia and Mazury are chernozem soils (northern part of the region in the area of Sępólno and Kętrzyn), brown soils (Mrągowo, Elk, Iława, Bartoszyce) and alluvial soils (mainly in Vistula and Pasłęka river deltas and the Lyra River valley). The least fertile soils are podzolic and pseudopodzolic soils in southern parts of the region.

Methodology

Natural conditions are the key determinants of rural development in the Region of Warmia and Mazury (Hopfer, Cymerman, Suchta 2002). The region's environmental potential which contributes to the development of agriculture and tourism was evaluated based on the data supplied by the Central Statistical Office. Environmental potential was assessed in view of primary natural factors, including soil, topography, water resources and flora. Natural features that are most conducive to the development of agriculture and tourism were selected based on the work of Stola (1993), Falkowski (1993), Bański (2002) and Gwiaździńska (2004).

The development and significance of agriculture is determined by various environmental factors. The following features were taken into account in this analysis:

1) farmland productivity index (FPI),
2) percentage share of agricultural area in the total area of a municipality (%),
3) percentage share of arable land in the the agricultural area of a municipality (%),
4) percentage share of meadows and pastures in the agricultural area of a municipality (%).

Numerical data for the evaluated features was summarized in a matrix where rows represented municipalities and columns were indicative of their individual characteristics. The features were normalized and expressed numerically for the needs of a comparison. The synthetic Perkal index was applied to the analyzed features to evaluate the region's environmental potential for the development of agriculture.

One of the key features investigated in this analysis was the farmland productivity index (FPI) which evaluates the four main natural factors: soil quality and fertility, climate conditions, landform and water conditions (Brodzińska 2012). Soil quality and fertility is the most important factor which can be assigned from 30 to 90 index points, followed by climate conditions (7 to 13 points), water conditions (2 to 5 points) and landform (1 to 5 points). The FPI for rural areas in the Region of Warmia and Mazury was determined at 65.4 points, and it approximated the national average of 66.6 points. The FPI for the Region of Warmia and Mazury ranged from 45.2 points in the municipality of Świętańno near Szczytno to 87.2 points in the municipality of Gronowo Elbląskie. FPI scores indicate that northern and north-western parts of the analyzed region have the most supporting conditions for agricultural production, whereas the southern parts are least suitable for farming (Fig 1.). The spatial distribution of scores awarded to local municipalities is closely correlated with soil quality and fertility, the most important evaluation criterion. The best soil conditions are observed in northern and north-western parts of the region due to the abundance of fertile chernozem, brown soils and alluvial soils. The lowest scores were noted in municipalities situated in the southern parts of the region which are characterized by the predominance of podzolic soils, rusty soils and grey-brown podzolic soils of low importance for agriculture.
The share of agricultural land in total area was analyzed as an indicator of agricultural productivity. In 2010, the share of farmland varied significantly across the analyzed region. It was the lowest (15%) in the municipalities of Ruciane-Nida, Jedwabno and Stawiguda which are occupied mainly by forests (Fig. 2). Similar results were reported in municipalities which are situated in southern parts of the region and are also characterized by the predominance of forests. The highest share of farmland (80%) was noted in the municipalities of Bisztynek, Barciany and Kowale Oleckie which are situated in northern parts of the region with mostly favorable soil conditions.

Based on the analyzed indicators, the investigated municipalities were grouped into one of four classes, ranging from class I characterized by the highest environmental potential for the development of agriculture to class IV marked by the lowest environmental potential for the development of agriculture. The above classes were identified on an interval scale of development indicators based on the arithmetic mean and standard deviation. In the group of 100 analyzed municipalities, 15 were identified as belonging to class I, 40 – class II, 29 – class III, 16 – class IV. The results of our analysis indicate that most municipalities with optimal conditions for agricultural development are situated in the northern part of the Region of Warmia and Mazury.

The development and significance of tourism is determined by various environmental factors. The following features were taken into account in this analysis:
1) percentage share of the area occupied by standing water bodies in the total area of a municipality (%),
2) percentage share of protected areas in the total area of a municipality (%),
3) percentage share of areas covered by forests, woods and shrubs in the total area of a municipality (%).

Numerical data for the evaluated features was summarized in a matrix where rows represented municipalities and columns were indicative of their individual characteristics. The features were normalized and expressed numerically for the needs of a comparison. The synthetic Perkal index was applied to the analyzed features to evaluate the region's environmental potential for the development of tourism.

Fig. 1. Farmland productivity index in the Region of Warmia and Mazury.
Source: Warunki przyrodnicze produkcji rolnej województw: elbląskiego, olsztyńskiego, 1979, IUNiG, Puławy,
Warunki przyrodnicze produkcji rolnej województw: suwalskiego, toruńskiego, 1982, IUNiG, Puławy,
Warunki przyrodnicze produkcji rolnej województwa ostrołęckiego, 1989, IUNiG, Puławy,

Fig. 2. Agricultural land in rural areas of the Region of Warmia and Mazury in 2010.
Source: www.stat.gov.pl
One of the key features investigated in this analysis was the percentage share of the area occupied by standing water bodies in the total area of a municipality (%) (Fig. 3). In rural areas of the Region of Warmia and Mazury, surface waters had an estimated 6.3% share of the region's territory. The share of surface waters varied significantly across the analyzed region, and it was the highest (20% and more) in the municipalities of Mikołajki, Giżycko, Tolkmicko and Frombork.

Figure 3. Surface water bodies in the Region of Warmia and Mazury
Source: M. Gwiazdzinska, 2004

In the following step of the analysis, the percentage share of protected areas in the total area of a municipality was investigated (%) (Fig 4). Protected territories span the area of 11,135,000 ha, and they are situated mainly (29.9%) in the municipalities of Dubeninki, Piecki, Mikołajki, Lidzbark Welski, Rybno and Tolkmicko which are characterized by unique orography, a high share of forests and diverse fauna and flora (Fig 4). An analysis of the spatial distribution of the protected areas indicates that the southern parts of the region have the highest potential for tourism development.

Figure 4. Protected areas in the Region of Warmia and Mazury.
Source: www.stat.gov.pl

Based on the analyzed indicators, the investigated municipalities were grouped into one of four classes, ranging from class I characterized by the highest environmental potential for the development of tourism to class IV marked by the lowest environmental potential for the development of tourism. The above classes were identified on an interval scale of development indicators based on the arithmetic mean and standard deviation. In the group of 100 analyzed municipalities, 17 were identified as belonging to class I, 23 – class II, 45 – class III, 15 – class IV. The results of our analysis indicate that most municipalities with optimal conditions for tourism development are situated in central and southern parts of the Region of Warmia and Mazury.

Development trends in the Region of Warmia and Mazury

The natural environment is an important determinant of rural development in the Region of Warmia and Mazury. Warmia and Mazury is a predominantly rural region where economic activities focus on agriculture, tourism, forestry and industrial processing (Województwo warmińsko-mazurskie. Plan zagospodarowania przestrzennego, 2001). The key economic drivers in the region are agriculture and tourism.
In the 1980s, Warmia and Mazury had the status of a predominantly agricultural region owing to an abundance of fertile soils. According to Stola (1993), municipalities with a predominantly agricultural profile accounted for 50% of rural municipalities in Warmia and Mazury. The region's land use profile varies subject to differences in environmental features. Those variations are illustrated by the share of agricultural land in total area, which is an indicator of agricultural productivity. In rural areas of the Region of Warmia and Mazury, agricultural land occupied 1,113,129,65 ha with an estimated 46% share of the region's territory.

Tourism is the second most important driver of the local economy. The Region of Warmia and Mazury is characterized by great scenic beauty which contributes to the development of tourism. The Masurian Lake District with its diverse relief and an abundance of water bodies is one of the most popular tourist destinations in summer. A waterway system connecting lakes and canals occupies 20% of the Land of the Great Masurian Lakes. The system begins with Lake Mamry in the north, it intersects Lake Niegocin and continues through ribbon lakes of Ryńskie, Talty, Mikołajskie, Beldany and Nidzkie. The Land of the Great Masurian Lakes features Poland's largest lake of Śniardwy (11,340 ha). The Great Masurian Lakes are renowned for their unique scenery, and they constitute one of the greatest tourist attractions in the country. Besides the Region of Warmia and Mazury is one of the most picturesque areas in Poland with a high degree of naturalness. Approximately 47% of the region's area receives some form of legal protection. Warmia and Mazury incorporates 8 landscape parks, more than 100 nature reserves (fauna, bird, forest, bog, landscape reserves) and more than 2000 monuments of animate and inanimate nature.

The results of our analysis indicate that 55 of 100 evaluated municipalities, 39 of which are situated in the central part of the Region of Warmia and Mazury, are characterized by high environmental potential for the development of agriculture (Fig. 4). Our findings also revealed that 44 of 100 investigated municipalities, 20 of which are found in the central part of the region, have a high environmental potential for the development of tourism (Fig. 4). Our results are consistent with the strategic development goals that have been set for Warmia and Mazury based on an analysis of the region's environmental and socio-economic indicators (Fig. 4 and Fig. 5). Natural conditions are the primary determinants of rural development in the Region of Warmia and Mazury.
The findings of Suchta (2002), Gwiaździńska-Goraj and Goraj (2011), Gwiaździnska-Goraj and Jezierska-Thöle (2013) also converge with the strategic development goals of the Region of Warmia and Mazury (Fig. 5). The majority of municipalities with a supportive environment for the development of agriculture are situated in the northern and eastern parts of the analyzed region. The municipalities in the central part of Warmia and Mazury are renowned for their high natural value and picturesque landscapes, and they offer vast opportunities for the development of tourism and recreation.

Conclusions

In view of its unique natural features, the Region of Warmia and Mazury has a high environmental potential for the development of agriculture and tourism. Until the late 1990s, Warmia and Mazury had the status of a predominantly agricultural region due to an abundance of fertile soils. Tourism is the second most rapidly developing branch of the local economy. Great scenic beauty and relatively low levels of environmental degradation make Warmia and Mazury one of the top tourist destinations in Poland. The region is characterized by natural diversity, and various tourist activities can be pursued around the year. The growing popularity of rural tourism has contributed to the development of agritourism facilities in the region. The natural environment is an element of sustainable development which affects social and economic growth. The results of our analysis indicate that the majority of municipalities with the highest environmental potential for the development of agriculture are situated in the northern part of the Region of the Warmia and Mazury which is characterized by favorable soil conditions, whereas the municipalities in the central and southern parts of the region have the highest environmental potential for the development of tourism.

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Response Reaction of Scots Pine *Pinus sylvestris* L. After Forest Fire in Forest Site Type *Vacciniosa turf. mel.* in Klīve Forest District

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**Abstract**

It is important to conduct studies on the fire impact in different forest site types in order to obtain information for the planning of forestry activities, financial gain or loss prediction after the forest fire. The topic is current because in the scale of Latvia there is no significant research about the fire impact on radial growth of trees.

The study analyzes impact of fire occurred nine years ago in middle-aged Scots pine stand growing in forest site type *Vacciniosa turf.mel.* During the research mortality of trees were compared and sanitary conditions in areas affected by the forest fire and in unaffected areas were evaluated as well as the analysis of forest fire impact on the dynamics of radial growth of the stand was carried out.

For the collection of empirical data five sample plots in the affected part by fire and five in unaffected part of the stand were established each 500 m² large. The diameter and height of trees and height of the scorched were measured, Kraft class were established, cores were taken for measuring the width of annual rings, and sanitary conditions were estimated listing cracked barks caused by fire, insect damages, bark openings at the root collar and exposed roots.

Analysis of the data shows that forest fire does not significantly affect the amount of tree mortality as evidenced by analysis of variance (p<0.05). In assessing the sanitary conditions it was found that between all tree damages after fire cracked bark have the greatest proportion (14%), followed by insect damaged trees (7%), trees with bark opening at the root collar (4%) and trees with exposed roots (3%). There is a significant difference between the number of cracked bark in different diameter groups and in the groups of the maximum height of scorching, most of them are found in diameter group up to 20 cm and in the maximum scorching group from 1.51 m to 2.00 m. The effect of fire impact on growth dynamics of tree stand is negative creating a volume reduction in average of 2 m³ ha⁻¹ per year. Overall volume reduction of stand since 2004 is 18.7±0.21 m³ ha⁻¹, potential loss reach 790.4 LVL i.e. 950.25 EUR.

**Key words:** forest fire, *Pinus sylvestris* L., dynamics of radial growth, sanitary condition, forest site type *Vacciniosa turf. mel.*

**Introduction**

Scots pine *Pinus sylvestris* L. is one of the three economically significant tree species in Latvia occupying 35% (1,003,625 ha) of the Latvian forests (State Forest Service, 2013). One of the treats to successful forest stand development is forest fire. The statistics of forest fire in Latvia over last twenty years show that occasionally extreme of fire are observed. In 2006 when the last extreme of fire was observed 3.8 thousand ha or 0.13% of Latvian forests development is forest fire. The statistics of forest fire in Latvia over last twenty years show that occasionally extreme of fire are observed. In 2006 when the last extreme of fire was observed 3.8 thousand ha or 0.13% of Latvian forests suffered from fire (State Forest Service, 2013). It is expected that within the next 100 years air temperature in Latvia in spring and summer - the most inflammable period - will increase on average by 3 °C and 2 °C respectively (Jansons, 2012) so it is necessary to pay more attention to forest fires and to analyze their impact on forest stand. In Latvia studies have been conducted on the tree including Scots pine, insects-dendrophages damage and vitality after forest fire but so far there are no major studies on dynamics of radial growth of pine after forest fire. Forest fire impact is among the actual themes where fire impact on ecosystems, soil and ash characteristics is researched (Pereira et al, 2012). The aim of the study is to evaluate the impact of forest fire on the growth of middle-aged Scots pine growing in forest site type *Vacciniosa turf.mel.* It was reached caring out tree scientific tasks: comparison of the proportion of tree mortality in the area affected by fire and unaffected area of the stand, analysis of the impact of forest fire on the radial growth of trees as well as assessment of stand sanitary conditions affected by fire and unaffected area of the stand. Researched forest stand covers an area are 4 ha. Nine years ago in 2004 there detected a forest fire. A fire type – creeping groun fire combined with shallow subsurface fire (Bušs, Vanags, 1987, Kronītis, 1972, Roga, 1979, Rokjānis, 2003), burnt area – 2 ha. The thickness of peat layer there was of an average of 22 cm.

**Research methods**

Empirical data material was collected in five circular plots in the forest stand part affected by fire and five in unaffected part of the stand, area of one sample plot was 500 m². For all of the trees in each plot diameter 1.3 m above root collar was measured, Kraft class (Kraft, 1884, Miezīte, 2013) was determined, measuring of peat layer was done, for 25 trees drilling towards to the centre of the plot at the height of 1.3 m above the root collar using Pressler borer was made. Tree height of all bored trees was measured (Liepa et al, 2013). Maximum height of scorching was measured; trees with insect damage, bark openings at the root collar caused by fire, trees with exposed roots and cracked barks were listed. Cracked bark is opened, by bark unprotected wood which is bounded by wood lumps and formed in the result of mechanical abrasion of bark, as well as in the result of fire (Vakins et al, 2013). Height at the root collar, length and width of the cracked barks were measured. For measuring of width of tree-rings Lin TAB system microscope was used. Data processing was made using computer software T-Tools Pro, Microsoft Office Excel and VidesFIV (Vides Faktoru Ietekmes Vērtēšana) computer software developed in Latvia University of Agriculture (Liepa et al, 2013). Mathematical calculations of the software are based on the algorithms given by professor I. Liepa.

Proportion of damaged or dead trees (P, %) is calculated using the following formula -
\[ P = \frac{n}{N} \cdot 100 \]  

where  
\[ n \] – number of damaged or dead trees, pieces ha\(^{-1}\);  
\[ N \] – total number of trees, pieces ha\(^{-1}\);

Results and discussion

Comparison of the amount of tree mortality in fire affected part and unaffected part of the stand

The proportion of deadwood in fire affected part and in unaffected part of the stand is not high (Table 1), it consists of IV and V Kraft class trees, so those who are already doomed – stunted, depressed by other trees, with small dimensions.

Table 1. Proportion of tree mortality in fire affected and unaffected area

<table>
<thead>
<tr>
<th>Sample plots (SP)</th>
<th>Total number of trees measured in SP pcs.</th>
<th>Number or healthy trees in SP, pcs.</th>
<th>Number of dried trees</th>
<th>Amount of dead trees, %</th>
<th>Volume of mean tree, m(^3)</th>
<th>Deadwood volume, m(^3) ha(^{-1})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fire affected part of the stand</td>
<td>219</td>
<td>212</td>
<td>7</td>
<td>28</td>
<td>3.2</td>
<td>0.4629</td>
</tr>
<tr>
<td>Fire unaffected part of the stand</td>
<td>196</td>
<td>191</td>
<td>5</td>
<td>20</td>
<td>2.6</td>
<td>0.4584</td>
</tr>
</tbody>
</table>

Tree mortality depending on their dimensions is also confirmed by research of J. Donis (2010). The results confirm that the smaller dimension trees have higher risk of mortality. In plots located in the part of stand affected by fire 7 trees were perished but in the unaffected part – five, respectively 28 and 20 trees ha\(^{-1}\) (3.2% and 2.6% of all trees). Deadwood volume in the area affected by fire is 13.0 m\(^3\) ha\(^{-1}\) and in unaffected area - 9 m\(^3\) ha\(^{-1}\).

Small difference of the amount of mortality between fire affected and unaffected part of the stand can be explained by the fact that pine has reached middle age and thicker bark has developed (Zviedre, Mangalis, 2003), crowns are significantly higher than the crowns of young trees, so resistance to fire is higher. This is confirmed by the research carried out in Finland, the results show that with the increase of the intensity of fire, scorches significantly increase in 15 to 45 year old pine stands but in 40 to 60 year old stands such effect has not been observed (Tanskanen, 2007). The results of Sidroff (2007) research indicate that the amount of tree mortality of \textit{Pinus sylvestris} L. stands decreases with age. Hypothesis that fire impact on the mortality of trees in forest stand is not significant in this object is confirmed by analysis of variance (\(F_{\text{stat.}} = 0.29 < F_{\text{crit.}} = 5.32, p = 0.607 > \alpha = 0.05\)).

Graphical representation of comparison of deadwood volume (Figure 1) shows that there is no significant difference between tree mortality in fire affected and fire unaffected area (\(\alpha = 0.05\)).

Figure 1. Comparison of deadwood volume (M±SE) in fire affected and fire unaffected area.

Forest fire impact on the dynamics of radial growth of tree stand

Forest fire impact on Scots pine radial growth is given in the graphs of changes of the width of annual rings in the fire affected plots and unaffected (control) plots (Figure 2) where thinline shows the width of annual rings of control stand (KONT), black line – widths of annual rings of trees affected by fire (VIV) but dash line – predicted widths of annual rings in the absence of fire impact. On the X-axis interval of years when annual rings were measured is given - the first six years is the period of retrospection but the next nine years is the period of the assessment of fire impact. On the Y-axis the widths of annual rings are given.
Dynamics of the Scots pine radial growth after forest fire in all fire affected plots is similar – with a negative trend in growth dynamics contrary to the results of K. Cirse (2013) where the results show a positive growth trend. The difference between both studies is due to the different forest site types included in research (forest stand on mineral soils and forest stand on peat soil) and fire type which in the case of K. Cirse is creeping ground forest fire but in current research - creeping ground forest fire combined with shallow subsurface fire.

Looking at the graph of changes of the overall width of annual rings in the fire affected plots and unaffected plots (Fig. 3) it can be concluded that forest fire has negative effect on radial growth of the stand. This potential result of forest fire is also noted by I. Liepa (1991).

Figure 2. Changes of the widths of annual rings in the fire affected plot and in control plots: a – first fire affected plot, b – second, c – third, d – fourth, e – fifth.

Figure 3. Changes of the width of annual rings in fire affected and fire unaffected plots and predicted widths of annual rings in the absence of fire impact.
Numerical comparison of mean values of the widths of annual rings in fire affected and fire unaffected plots before and after fire (Table 2) shows that evaluating the width of annual rings in the borders of sample plots before and after fire the average width is 0.11 ± 0.018 mm narrower and in comparison of control stand - 0.18 ± 0.030 mm.

Table 2. Difference of mean width of annual rings between control and fire affected plots before and after forest fire

<table>
<thead>
<tr>
<th>Time</th>
<th>Sample plot</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fire affected_1SP</td>
<td>Fire affected_2SP</td>
</tr>
<tr>
<td>After forest fire</td>
<td>-0.26 ± 0.029</td>
<td>-0.05 ± 0.034</td>
</tr>
<tr>
<td>Before forest fire</td>
<td>-0.16 ± 0.025</td>
<td>0.06 ± 0.032</td>
</tr>
<tr>
<td>Difference of widths</td>
<td>-0.10 ± 0.023</td>
<td>-0.11 ± 0.027</td>
</tr>
<tr>
<td>of annual rings after</td>
<td></td>
<td></td>
</tr>
<tr>
<td>forest fire</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table shows the average values obtained from the difference of the width of annual rings between plots affected by fire and unaffected plots. Negative numbers indicate that annual rings obtained in the plots affected by fire are narrower than in fire unaffected (control) plots while positive ones – to wider annual rings in the fire affected than the unaffected part of the stand. The table shows that the negative growth increases after the fire.

The effect of fire impact (Fig. 4) illustrates the negative impact of forest fire on trees in the research object. Plots are encrypted under the following names: the first plot in fire affected area - „Fire affected_1SP”, the second – „Fire affected_2SP” and as follows.

Figure 4. The effect of forest fire impact in the fire affected plots.

Significant negative growth was observed in the fourth and fifth plot which can be explained by the relatively large amount of cracked barks caused by fire in these plots. Fluctuations by years hypothetically can be explained by the impact of meteorological factors and the amount of ash formed as result of ground vegetation, litter and undergrowth combustion. Nesterovs (1954) notes that the ash formed from low intensity forest fire encourages the growth of forest stand. In the second, third and fourth plot growth conditions in the second year although the impact effect is still negative have improved. This can be explained by combustion caused ash disposal and infiltration in the soil. In later years the existing fluctuations between plots can be explained by meteorological factor what accumulates in the result of stand heterogeneity. The third plot line is placed between the first and the second as well as of the fourth and fifth plot.

As the result of forest fire an average of 2 m³ ha⁻¹ of additional growth are lost every year, in nine years since the forest fire makes a total of 18.7 ± 0.21 m³ ha⁻¹.

Sanitary conditions in the fire affected part and unaffected part of the stands territory

In the research object sanitary conditions were evaluated in four categories: trees with cracked barks caused by forest fire, insect damaged trees, trees with bark openings at the root collar, trees with exposed roots. As you can see in the graph of damage intensity (Fig. 5) the sanitary conditions in fire unaffected area are good, but in fire affected part of the stands cracked barks can be observed in the 14% of cases, insect damage occur in 7% of cases, bark openings at the root collar and exposed roots can be observed in less than 4% and 3%, respectively.
As the most common damage is cracked bark incidence of it in different tree diameter and maximum height of scorching groups was analyzed. Evaluating different diameter groups it should be marked that cracked barks are the most observed in group up to 20 cm and 20-25 cm, 64 pieces ha\(^{-1}\) and 48 pieces ha\(^{-1}\) respectively (Fig. 6). There is no significant difference between these two groups in the number of cracked barks but between them and the number of cracked barks in diameter rating group > 25 cm a significant difference appears.

Number of cracked barks is significantly different among scorching height groups while between the first, the third and the fourth group there are not significant differences. Significant difference is between the fifth (8 pieces ha\(^{-1}\)) and the other height groups.

Dead wood and lost potential wood increase after forest fire in the evaluated forest stand reach 704.14 LVL i.e. 950.25 EUR (Table 3).
Scots pine round wood purchase parameters from Ltd. „BALTIC TIMBER.LV“ (www.baltictimber.lv) and average pulpwood purchase price from www.mezi.lv were used, currency rate from www.swedbank.lv was used (14.06.2013.).

**Conclusion**

In researched stand forest fire does not significantly affect the amount of tree mortality ($F_{stat} = 0.29$,$F_{crit} = 5.32$, $\alpha = 0.05$).

In the fire affected part the annual tree rings is narrower than in unaffected part of the stand, difference reach 0.18±0.030 mm.

Forest fire has a negative effect on the growth of researched stand. Each year the average wood loss reaches 2 m³ ha⁻¹. Nine years after the forest fire forest owner has already lost 18.7±0.21 m³ ha⁻¹ or 704.14 LVL i.e. 950.25 EUR from the stand.

Fire exposure in researched stand not only has a negative impact on growth but it also worsens sanitary condition of stand. After forest fire fire caused cracked barks (14%), insect damage (7%), bark openings at the root collar (4%) and exposed roots (3%) are observed.

The number of cracked barks is significantly different in several diameter groups and maximum height of scorching groups.

Most cracked barks are found in diameter groups up to 20 cm and 20-25 cm and the maximum height of scorching group from 1.51 m to 2.00 m.

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Employing Used Railway Ties for Retaining Walls Construction on Forest Roads – A Three Level Approach: Ecology, Economy and Technical Prescriptions

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Abstract

Efficient utilization of the timber products from Romanian forests can be realized only through the existence of a well-developed forest roads network which to provide the optimum transportation cost parameters. In the actual conditions, with a forest roads density of only 6.5 m/hectare there appears to be necessary the construction of new forest roads, as well as the rehabilitation of the damaged existent ones. Due to the fact that the forest resources from Romania are, in their majority, distributed in the increased slope mountainous conditions, the retaining walls are well-represented constructions on the forest roads, involving in their realization a large amount of materials and logistics. Currently, the majority of the retaining walls are constructively realized from cast-in-place concrete or combined rock-concrete mixture. The concrete utilization involves high costs as well as increased Green House Gases (GHG) emission. By comparison, some more ecological and economical solutions may be used in the retaining walls construction, like the utilization of out-of-use railway ties, saving this way money, materials, and space. On the other hand, an important economy may be attained in the carbon cycle. Paper presents aspects such as the possibility of use of out-of-use railways ties as construction material for the retaining walls, available resources, and cement quantities reduction in forest roads construction. Necessary quantities of material, involved costs and GHG emissions for different constructive solutions are treated as well minimum.

Key words: railway ties, retaining walls, recycling, economy, carbon emissions

Introduction

Short overview on forest roads current situation in Romania

Efficient utilization of the forest products from Romanian forests can be realized only through the existence of a well-developed forest roads network which to provide the optimum transportation cost parameters (Oprea, 2008) which could enable also the use of short distance cable yarders which currently are rarely used in Romania (Borz et al., 2011). In the actual conditions, with a forest roads density index of only 6.5 m/hectare (Bereziuc et al., 2011) there appears to be necessary the construction of new forest roads, as well as the rehabilitation of the damaged existent ones. Due to the fact that the forest resources from Romania are, in their majority, distributed in the increased slope mountainous conditions, the retaining walls are well-represented constructions on the forest roads, involving in their realization a large amount of materials and logistics. The specificity of the forests distribution in Romania generates well represented engineering works (artworks as well as protection and consolidation of embankments) on the forest roads (Varjoghe, 1996): over 1,200 bridges totalising more than 20 km in length, over 170,000 culverts, and, especially, over 5,000,000 meters of retaining walls. Currently, the majority of the retaining walls are constructively realized from cast-in-place concrete or combined rock-concrete mixture (Varjoghe, 1996). The concrete utilization involves high costs as well as increased Green House Gases (GHG) emission.

Out-of-use pre-stressed railway ties as a potential construction material

Pre-stressed concrete ties were introduced to the national railways construction starting from 1959, currently being used three base types (Railways. Part I, 1975): T6, T8 and T16. The mentioned ties were realized at 2.50...2.60 meters in length having trapezoidal cross-section, maximum width of 26 or 30 cm and heights of 19.70 and 21.50 cm. They present a thinner section in the middle part by comparison with the extreme edges. No matter their type, the railway ties are realized from C40/50 (Practice code for the realization of constructions from concrete, 2007) class concrete, which is pre-stressed at 42N/mm² using reinforcement steel bars. The reinforcement steel bars are uniformly distributed in the cross-section; usually there is used 12 x 3Φ3 reinforcement pattern (12 fascicules containing three SBP of φ3 mm wires each). Currently, the majority of the ties from the Romanian railways are being replaced because they attained their serviceability. This way, all major train stations are the hosts of important stacks of ties. Also, the total length of the Romanian national railways is of 22,247 km (www.wikipedia.ro) and different projects of construction and rehabilitation are these days considered from the last ones resulting important quantities of out-of-use ties which can be recycled (reused) in other constructions (www.mt.ro). The existing resources of ties present the important property of being stored in relatively accessible locations, grouped together and making this way possible a feasible transport. There can be mentioned that some railways materials may be used for other purposes (Order 1403, 2006).

Retaining walls

Because the Romanian forest roads are developed mostly in mountainous areas in increased slope conditions, the retaining walls are usually required in order to stabilise both, fill and cut grades (Bereziuc et al., 2006). Forest roads construction or rehabilitation (without artwork and crossing works) involves quite high costs (Official Monitor of Romania, 2010), and since the artworks represent an important fraction from forest roads construction (Varjoghe, 1996), the resulting costs may be quite high. If there is considered that the retaining walls represent almost 15% from the entire national forest roads network length (Varjoghe, 1996), cost-effective and environmentally sound solutions...
have to be identified and used for the realization of the first ones. Usually, there is used massive masonry or concrete walls (achieving their function by their weight) whose dimensions are determined by the heights and grades of the earth massive to be retained (Varjoghe, 1996; Bereziuc et al., 2006). Masonry walls present the advantage of using local construction materials but they involve an important labour investment, reason for which, many times, concrete retaining walls are used (Bereziuc et al., 2011; Varjoghe, 1996; Bereziuc et al., 2006). The last ones are usually advantageous from the labour investment point of view but are more expensive, especially if there are considered the requirements of national standards (Practice code for the realization of constructions from concrete, 2007) regarding the utilization of superior concrete types. Superior concrete types involve more energy consumption in order to realize the construction due to the supplementary required quantities of cement (Practice code for the realization of constructions from concrete, 2007). This way, the resulted solutions can be very intensive if the costs and GHG emissions are considered. By comparison, some more ecological and economical solutions may be used in the retaining walls construction, like the utilization of out-of-use concrete railway ties, saving this way materials, money and space. On the other hand, an important economy may be attained in the carbon cycle, due to the reuse of ties and emission savings resulted from the last’s utilization.

Aims
As presented above, the specific geographical distributions of the forests form Romania involves the realization of forest roads which may be very expensive due to the increased number (lengths) of the retaining walls. Finding cost-effective and environmentally sound solutions for the construction of the retaining walls represents a major preoccupation of these days. Masonry walls are labour intensive whereas concrete walls are cost and environment impact intensive. In this context, the paper’s aims are to: (i) identify new cost-effective and environmentally sound solutions for retaining walls construction, (ii) test the identified solutions using scientific approaches and (iii) compare the identified solutions with traditional ones by considering the environmental impact, economic issues and technical prescriptions, with special focus on the environmental and economic issues.

Research Methodology

Basic approach for designing new constructive solutions of retaining walls
Wood encasing walls were used in the past as retaining walls (Bereziuc et al., 2011; Bereziuc et al., 2006) and they can still represent a feasible solution these days, especially for fill grades when the roads are developed in the proximity of a river which can maintain the wood in a permanently wet state, assuring this way the construction durability (Bereziuc et al., 2011; Bereziuc et al., 2006). An alternative solution may be represented by the encasing retaining walls realized from used concrete railway ties, which can adapt easily to the terrain and its deformations, being in the same time advantageous from the cost point of view, due to the fact that they may be seen as a recyclable material which can be acquired at reduced costs. The new constructive solutions which are presented in the following paragraphs were designed initially by using AutoCad Civil 3D software, which helped in evaluating the necessary quantities of materials for different constructive solutions. For each constructive solution were performed resistance calculations using a simple Visual Basic for Applications (V.B.A.) program developed in MS Excel.

Description of the new constructive solutions
Encased retaining walls realized from ties
This solution (Figure 1), involves the realization of encasing retaining walls by vertical lapping of the ties, in a successive application on two perpendicular directions (parallel to the wall and perpendicularly on the wall), creating this way the shape of a box with empty spaces having the height of a tie. The resulting joints are assembled using cast-in-place concrete, realizing this way resistance pillars which are fixed in concrete foundations, enabling this way their overtaking and transmission of the loads to the foundation. The pillars can be realized also using reinforced concrete constructive variant, by introducing longitudinal reinforcing steel bars in the four corners and clamps at each second tie, which are mounted in the same time as the ties are. In this last case, more supple pillars can be used, involving this way a more reduced consume of concrete. Another variant of the corners joining may involve the pre-stressing of the pillars (which contain the ties) by fixing in the foundations (at their realization) of some pre-stressing reinforcements on each side of the ties wall. This way, after the ties positioning, the overall wall will be pre-stressed. After the ties mounting and consolidation, the interior space delimited by them is filled with granular material (Figure 2). A special function of the presented constructive solution resides in the fact that, by comparison with the traditional solutions, they ensure better the earth massive drainage; for solving the movement of fine material as the result of water activity a geo-textile film can be introduced in the resulted box.

Retaining walls realized from ties and ties-reinforced pillars
In the case of this constructive solution, the ties are successively positioned on vertical direction and their edges are jointed together by cast-in-place concrete pillars, which, in order to overtake the stretching stresses are reinforced with pre-stressed ties (Figure 3).
Figure 1. Cast-in-place concrete encasing walls – front perspective (a) and back perspective (b)

Figure 2. Cast-in-place concrete encasing walls – up perspective: 1 – tie, 2 – concrete pillar, 3 – granular material filling

Figure 3. Retaining walls realized from ties and tie-reinforced pillars: a – overall construction, back view (1 – tie, 2 – brace tie, 3 – pillar, 4 – foundation), b – side view, c – front view (outside the road)

The ties joins are reinforced by cast-in-place concrete pillars, realizing this way resistance pillars which are fixed in a concrete foundation. This way, the earth massive loads are taken and transmitted to the foundation. For this constructive solution, pillars can be also realized in a steel reinforced concrete variant, using a longitudinal reinforcement in the four corners and clamps at each second tie (clamps are mounted during the ties positioning phase). In this last case, more supple pillars can be used, involving this way a more reduced consume of concrete. Like in the case of the previously presented solution the corners joining may be done by pre-stressing the pillars; this way, there are fixed in the foundations (at their realization) some pre-stressed reinforcements on each side of the ties wall. After ties positioning, the resulted wall is pre-stressed.

According to figure 3, the brace (2) has the role of maintaining the link between the pillar (3) and the foundation (4). This way, a more supple constructive assembly is realized having a reduced weight which could create premises for the wall sliding. In order to avoid that, the pillars can be weighted using horizontally positioned ties on the foundation, which will contribute to the wall’s overall stability through the earth mass discharge over the foundation. The foundation can be reinforced at the superior part using a concrete arm having the role of overtaking the stretching efforts which could appear in this section.
The constructive variant from figure 4 presents the same constructive characteristics excepting that the tie which acts as a brace in the overall assembly is contained in the cast-in-place concrete pillar. The pillar’s foundation is realized using a greater length than of the pillar’s itself in order to improve the overall stability of the construction assembly.

![Figure 4](image_url)

Figure 4. Retaining walls realized from ties and tie-reinforced pillars: a – back view (b – front view (outside the road))

**Results**

Environmental and economic assessment

**Comparison assumptions**

Comparison between different constructive solutions may be difficult due to the specific technical prescriptions of each one apart. In order to assess the differences between the presented and traditional solutions, a common ground has to be identified for comparison purposes, which to describe the necessary dimensions as well as the necessary materials and investments. For this paper purpose, there were made the following assumptions:

- Four constructive variants were considered: A – traditional cast-in-place concrete retaining walls, B – cast-in-place concrete encasing walls, C1 - retaining walls realized from ties and tie-reinforced pillars without contained brace and C2 - retaining walls realized from ties and tie-reinforced pillars with contained brace;
- Total calculation length corresponds to a length which incorporates all the necessary structural elements of an assembly for its function realization, making this way possible the comparisons between necessary quantities of materials, GHG emissions and the involved costs;
- The calculation height corresponds to the limitations imposed by the proposed construction solutions;
- Costs and GHG emissions are considered for the following processes: raw materials extraction, manufacturing, transport, and site construction (no material disposals considered due the fact that the resulted materials after the life cycle can be used by incorporation in other local constructions);
- The results regarding the necessary materials (Table 1), GHG emissions (Table 2) and the economical assessment (Table 3) were calculated for one linear meter of construction in the following conditions: calculus convey A10, S30 and ATF 25 (Bereziuc et al., 2006), earth density of 1.8 kN/m\(^3\), an internal friction angle on 33º and a foundation-earth friction coefficient of 0.5.

**Comparison results**

Table 1 presents the list of necessary materials in order to realize the compared constructive solutions. All the constructive solutions involve the use of concrete, but the proposed ones provide significant concrete economies, reflected throughout all the involved processes (Table 1). This is generally true also in the case of the necessary quantities of reinforcing steel bars. Important economies may be attained due to the reduction of necessary materials as a consequence of the concrete replacement by ties.

**Table 1. Necessary materials for the constructive solutions realization**

<table>
<thead>
<tr>
<th>Specifications</th>
<th>Measurement unit</th>
<th>A</th>
<th>B</th>
<th>C1</th>
<th>C2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elevation concrete</td>
<td>m(^3)</td>
<td>3.25</td>
<td>0.78</td>
<td>1.18</td>
<td>0.98</td>
</tr>
<tr>
<td>Foundation concrete</td>
<td>m(^3)</td>
<td>1.18</td>
<td>0.63</td>
<td>1.22</td>
<td>1.22</td>
</tr>
<tr>
<td>Casts</td>
<td>m(^3)</td>
<td>6</td>
<td>9.2</td>
<td>11.6</td>
<td>10.2</td>
</tr>
<tr>
<td>Reinforcements (steel bars)</td>
<td>kg</td>
<td>-</td>
<td>14.2</td>
<td>18.6</td>
<td>17.3</td>
</tr>
<tr>
<td>Out-of-use ties</td>
<td>pieces</td>
<td>-</td>
<td>10</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Earth cuts</td>
<td>m(^3)</td>
<td>4.2</td>
<td>3.82</td>
<td>3.66</td>
<td>3.50</td>
</tr>
<tr>
<td>Materials transport</td>
<td>kilometric tone</td>
<td>200</td>
<td>86</td>
<td>108</td>
<td>96</td>
</tr>
</tbody>
</table>

Different needed processes for the constructive solutions realization involve different GHG emissions. For this paper purpose there are evaluated the CO\(_2\) emissions associated with the raw material extraction, manufacturing, transport and site construction. The emissions are correlated with the necessary materials for realizing the constructive solutions presented in table 1 as well as with the involved processes. Carbon dioxide emissions were determined according to the LCI-LCIA Product Reports (Cement and Structural Concrete Products, 2005; Cradle-to-Gate Life cycle
inventory, 2002), as well as from other sources (Environmental impact of concrete, 2012). The supplementary emissions due to the used means for extraction, transport and on-site construction were considered outside the investigated system’s boundaries (Frenette et al., 2012). The results regarding GHG emissions (CO₂) for the compared constructive solutions are presented in Table 2.

Economic assessment of the proposed solution by comparison with the traditional ones is presented in Table 3. Costs are calculated by taking in consideration of Romanian produced resources (no imports for any needed materials). The presented costs include all the costs stated by Romanian legislation. Prices for different components were obtained as average for the main Romanian producers.

Table 2. GHG emissions involved by the realization of the constructive solutions

<table>
<thead>
<tr>
<th>Specifications</th>
<th>GHG (CO₂) emissions, expressed in kg per linear meter of construction</th>
<th>A</th>
<th>B</th>
<th>C1</th>
<th>C2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elevation concrete</td>
<td>715,00</td>
<td>171,60</td>
<td>259,60</td>
<td>215,60</td>
<td></td>
</tr>
<tr>
<td>Foundation concrete</td>
<td>236,00</td>
<td>126,00</td>
<td>244,00</td>
<td>244,00</td>
<td></td>
</tr>
<tr>
<td>Casts</td>
<td>0,54</td>
<td>0,83</td>
<td>1,04</td>
<td>0,92</td>
<td></td>
</tr>
<tr>
<td>Reinforcements (steel bars)</td>
<td>0,00</td>
<td>36,92</td>
<td>48,36</td>
<td>44,98</td>
<td></td>
</tr>
<tr>
<td>Out-of-use ties</td>
<td>0,00</td>
<td>0,00</td>
<td>0,00</td>
<td>0,00</td>
<td></td>
</tr>
<tr>
<td>Earth cuts</td>
<td>3,36</td>
<td>3,06</td>
<td>2,93</td>
<td>2,80</td>
<td></td>
</tr>
<tr>
<td>Materials transport</td>
<td>30,00</td>
<td>12,90</td>
<td>16,20</td>
<td>14,40</td>
<td></td>
</tr>
<tr>
<td>Total constructive solution</td>
<td>984,90</td>
<td>351,30</td>
<td>572,13</td>
<td>522,70</td>
<td></td>
</tr>
</tbody>
</table>

Table 3. Economic assessment of the constructive solutions

<table>
<thead>
<tr>
<th>Specifications</th>
<th>Measurement unit</th>
<th>Involved costs for constructive solutions realization, expressed in euro/linear meter of construction</th>
<th>A</th>
<th>B</th>
<th>C1</th>
<th>C2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elevation concrete</td>
<td>euro</td>
<td>224,40</td>
<td>53,86</td>
<td>81,48</td>
<td>67,67</td>
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</tr>
<tr>
<td>Foundation concrete</td>
<td>euro</td>
<td>70,24</td>
<td>37,50</td>
<td>72,62</td>
<td>72,62</td>
<td></td>
</tr>
<tr>
<td>Casts</td>
<td>euro</td>
<td>21,43</td>
<td>32,86</td>
<td>41,43</td>
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<tr>
<td>Reinforcements (steel bars)</td>
<td>euro</td>
<td>0,00</td>
<td>16,90</td>
<td>22,14</td>
<td>20,60</td>
<td></td>
</tr>
<tr>
<td>Out-of-use ties</td>
<td>euro</td>
<td>0,00</td>
<td>14,29</td>
<td>7,14</td>
<td>7,14</td>
<td></td>
</tr>
<tr>
<td>Earth cuts</td>
<td>euro</td>
<td>10,00</td>
<td>9,10</td>
<td>8,71</td>
<td>8,33</td>
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</tr>
<tr>
<td>Materials transport</td>
<td>euro</td>
<td>47,62</td>
<td>20,48</td>
<td>25,71</td>
<td>22,86</td>
<td></td>
</tr>
<tr>
<td>Total constructive solution</td>
<td>euro</td>
<td>373,69</td>
<td>184,98</td>
<td>259,24</td>
<td>235,64</td>
<td></td>
</tr>
</tbody>
</table>

As there can be seen in Tables 2 and 3, the highest impact in terms of CO₂ emissions and costs) is presented by the traditional constructive solution (A). In this case, the increased GHG emissions are associated with raw material extraction, and, especially with manufacturing processes, due to the fact that the last mentioned processes involve several manufacturing stages which are characterized by emission-intensive states (Cement and Structural Concrete Products, 2005; Cradle-to-Gate Life cycle inventory, 2002). Traditional retaining walls are weight based solutions, fact which involves great consumes of cast-in-place concrete. Due to the fact that the Romanian standards (Practice code for the realization of constructions from concrete, 2007) require the utilization of superior concrete types, the necessary cement quantities for the retaining walls realization are increased, leading to supplementary GHG emissions. By comparison, the proposed constructive solutions (Table 2) reduce the GHG emissions with 64.40% (B), 41.91% (C1) and 46.93% (C2) respectively. This economy results, mainly, from different utilization rates of the cast-in-place concrete, as well as from the reduction of the transportation distances (out-of-use ties are concentrated in more accessible places whereas the cement plants are quite dispersed). From the GHG emissions point of view, the best solution is the constructive solution B, which, due to the increased number of used ties, provides a major economy in case of the necessary cast-in-place concrete. However, this solution may require important quantities of geo-textile film in order to attain its functionality.

The necessary quantities of cast-in-place concrete dictate also the economic investments for the constructive solutions realization, since the situation regarding the involved costs is practically the same. The utilization of the proposed constructive solutions may result in important economies since they are cheaper with up to 50.50% (B). If there are compared the proposed technical solutions, there results that solution B is the cheapest one (184.98 euro/linear meter by comparison with solutions C1 - 259.24 euro/linear meter and C2 - 235.64 euro/linear meter). However, future practice applications are necessary in order to determine the real stability of the proposed solutions, as well as their behaviour during life time. A short comparison between the constructive solutions C1 and C2 may indicate, at a first glance, the superiority of the last one from the overall construction’s stability point of view, but the investments are greater with approximately 9%. 

As there can be seen in Tables 2 and 3, the highest impact in terms of CO₂ emissions and costs) is presented by the traditional constructive solution (A). In this case, the increased GHG emissions are associated with raw material extraction, and, especially with manufacturing processes, due to the fact that the last mentioned processes involve several manufacturing stages which are characterized by emission-intensive states (Cement and Structural Concrete Products, 2005; Cradle-to-Gate Life cycle inventory, 2002). Traditional retaining walls are weight based solutions, fact which involves great consumes of cast-in-place concrete. Due to the fact that the Romanian standards (Practice code for the realization of constructions from concrete, 2007) require the utilization of superior concrete types, the necessary cement quantities for the retaining walls realization are increased, leading to supplementary GHG emissions. By comparison, the proposed constructive solutions (Table 2) reduce the GHG emissions with 64.40% (B), 41.91% (C1) and 46.93% (C2) respectively. This economy results, mainly, from different utilization rates of the cast-in-place concrete, as well as from the reduction of the transportation distances (out-of-use ties are concentrated in more accessible places whereas the cement plants are quite dispersed). From the GHG emissions point of view, the best solution is the constructive solution B, which, due to the increased number of used ties, provides a major economy in case of the necessary cast-in-place concrete. However, this solution may require important quantities of geo-textile film in order to attain its functionality.

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Conclusions

Currently, the scholars from different domains try to find environmental sound and cost effective solutions for the infrastructure realization in varying domains. Forest represents one of the main resources which contribute to the environmental equilibrium, but the conservation of its functions cannot be done without the existence of an adequate infrastructure which to provide an integral accessibility. Due to the last mentioned aspect, major problems such pests and diseases, fire, wind-throws etc. cannot be managed correspondingly. In other words, forest roads construction has its impact on the environment, but a sustainable forestry cannot be realized without roads. A key aspect in forest roads construction is directly related to the used materials. Due to the fact that forest roads are regarded as relatively cheaper constructions by comparison with the public transportation infrastructure, the approved investments in their construction are quite reduced by comparison. In this context, finding better solutions, like those proposed in this paper are welcomed. As demonstrated, there can be realized better solutions, both, in term of GHG emissions and involved cost. In fact, great economies may be attained for the both indicators (up to 64.5% reductions in GHG emissions and up to 50.5% cost reductions). There may be considered also, other important factors such as the recycling of materials (railway ties), transport distances reduction due to the availability of the necessary materials in concentrated points at shorter distances by comparison with the availability of the necessary materials for the traditional solutions, reduction of the GHG emissions which result from raw materials extraction and manufacturing, as well as the utilization of a material which is reinforced with steel bars, fact that may lead to increased resistance and better behaviour of the construction.

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Approaches for the Planning of Forest Roads Network According to Environmental Impact Assessment

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Democritus University of Thrace, Greece

Abstract

Forest roads network development has several implications economical and ecological. Using GIS allows using large data sets and offers the opportunity to have a better approach incorporating information into a unitary system. The aim of this article is to underline the increasing accessibility and usefulness of GIS programs in road network development.

In this study it is proposed a methodology for producing an erosion raster grid in an area where it will be constructed a road network and quantifying it in the activity of road network planning. Using algorithms to generate the most convenient road paths, it has been developed a methodology for choosing the best path for the network, taking into consideration the environmental impact not for the present economic fares but for the future fares (road maintenance, rehabilitation etc.).

The method of quantification soil erosion in a forest perimeter situated in the Brasov County was adapted for usage in a GIS environment. The method itself was based on distinct sample plots with geographic reference. Plots' description was mainly used to observe the type and the vegetation status. The role of plots' positioning was to observe the homogeneous areas in order to create a mapping of the whole area. The characterization of territory through the erosion process in each sample plot was realized with Ciortuz method, which is a system based on indexes frequently used in science (geography) and in technology (silvotechnique).

The results of this study validated the new presented methodology of planning forest roads network taking into consideration environmental impact.

Key words: environmental impact assessment, forest roads network, soil erosion, open-source GIS.

Introduction

The development of the road network must ensure accessibility in the forest in order to realize the complex work of forest administration.

The most important factor, beside the technical ones, is the economic one for planning and development of the road network. A road should be ideal, cheap and should provide a maximum transport of wooden mass in order to be completely used in the process of exploitation (Pentek et al, 2005). Due to nature diversity, this is not possible in day to day life.

On the basis of economic criteria, Woodam Chung and Dr. John Sessions (2000) have developed a program (Network 2000) which underlines the most convenient way between a wooden mass point and the deposit platform (using intermediary points, the quantity of wooden mass to be transported/carried, the transport cost and the road cost). This program is based on an algorithm derived from J. Sullivan’s Algorithm developed in 1974. The algorithm generates alternative routes for each sale using the route approach of the Timber Transport Model (Sullivan 1974) combined with use of equivalent variable costs that was the foundation of the Prorate Option (Schnelle 1980). Then, it optimizes each route using the Simulated Annealing heuristic while considering multiple goals and side constraints of the problem (Chung and Sessions, 2001). The basic process of the algorithm is presented in the following four steps and illustrated in Figure 1.

Figure 1. Flowchart for Network 2000 algorithm (Chung and Sessions, 2001)
The NETWORK 2000 program takes into consideration only the economic criterion, the volume and the wooden mass.

The algorithm is based on the following objective function:

\[
f(x) = \sum_{i=1}^{n} \left[ (\text{var} \_\text{cost} \_i \cdot \text{vol} \_i) + (\text{cost} \_\text{fixat} \_i \cdot B_i) \right]
\]

where:
- \text{var} \_\text{cost} – the cost for the wooden mass volume transport in the point (i) ($/\text{vol.})
- \text{vol} – the volume for point (i),
- \text{cost} \_\text{fixat} – the fixed cost for point (i); how much money is spent to reach the point.

The ecological factor is very important in developing the road network. To prevent environment destruction due to road network development, a suitable indicator would be establishing the degree of soil erosion (Cochrane, 2007 et al.). This is why in this study it is proposed a methodology for creating an erosion raster grid in an area where it will be constructed a road network and quantifying it in the future activity of road network planning.

Using visual data obtained in the field, in geographically placed sample plots it has been developed a methodology for mapping erosion choosing the best path for the network, taking into consideration the environmental impact.

**Methods and Material**

The location of the study site is in Tarlung Basin, The mentioned watershed (with a surface of 184.37 km\(^2\)) is located in the mountainous area of Brașov (25° 48′ E, 45° 30′ N) and it is an area with high forest cover. From the point of view of the altitude, the watershed lies between 730 m and 1875 m, the average annual precipitation amount varies from 800 mm up to 1800 mm, and the lithological substrate is made of sedimentary rocks (predominantly lime grit stones).

![Location of the study area](image_url)

Figure 2. Location of the study area

Soil erosion assessment was made on 56.5 hectares area situated in the Tarlung basin (Brasov County). The most dangerous type of erosion is the one caused by rain. This type of erosion takes place as a natural process on all the bended grounds but it reaches brutal forms only in certain conditions. Therefore, each territory has a certain degree of erosion. There are certain factors which intervene in the process of rain erosion: the lithologic layers, the relief, the climate, the soil, the vegetation and the human factor. Moreover, if the bedrock, the relief, the climate and the soil become circumstances to accelerate the process, the vegetation, especially the forest one, protects the ground.

The method used in this study to characterize a territory through the erosion process was the Ciortuz method (Ciortuz, Pacurar, 2004), which is a system based on indexes frequently used in science (geography) and in technology (silvotechnique). The Ciortuz working system refers to the following factors: the rock type from the bedrock, the territory’s morphological slope, the rain factor, the soil texture and the vegetative factor (table 1). The indexes’ sum for the first four terms, meaning the erosion factors, show / reflect a certain predisposition to erosion. The fifth factor, vegetative factor, is the resistance one, thus the mathematic difference between average values of this index and the total of the other 4 indexes creates an erosion index which can reflect the territory’s degree of erosion.
Thereby, Ciortuz proposes this formula for quantifying soil erosion using an index:

\[ E = \frac{(R + I + P + T) + 2 \cdot V}{4} \]  

(2)

where \( R, I, P, T \) and \( V \) factors are explained in table 1.

Table 1. Index table of quantifying variables

<table>
<thead>
<tr>
<th>No.</th>
<th>Index symbol and explanation</th>
<th>Existent situations</th>
<th>Index value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Rock R</td>
<td>Low eroding bedrock</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Medium eroding bedrock</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>High eroding bedrock</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>Slope I</td>
<td>gradient until 10% in watershed and until 20% on the slope</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>gradient between 11-30% in watershed and between 21-60% on the slope</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>gradient over 31% in watershed and over 60% on the slope</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>Rain factor P</td>
<td>precipitations until 600mm</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>precipitations between 601-1000 mm</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Precipitations over 1000 mm</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>Soil texture T</td>
<td>Medium texture</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Light texture</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fine texture</td>
<td>3</td>
</tr>
<tr>
<td>5</td>
<td>Vegetative factor V</td>
<td>Commons and agricultural plants</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Low productive pastures and woods</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Normal pastures and woods</td>
<td>3</td>
</tr>
</tbody>
</table>

Figure 3. Location of sample plots a) On satellite image b) On slope raster

The material of this study was constituted from index quantifications for rock, slope, rain, soil and vegetation in 8 sample plots situated in representative points of the study area. Each plot has been measured with a GPS Garmin 60CSx receiver. The medium GPS accuracy was extracted using Garmin MapSource native application and it has been
of ±4m (table 2). Plots’ description was mainly used to observe the type and the vegetation status and to verify the slope calculated from DEM (digital elevation model) (figure 3).

The method proposed in this paper introduced in NETWORK 2000 objective function an index calculated through Ciortuz Method \( I_c \) it has been inserted it into the program’s algorithm, in its objective function.

\[
f(x) = \sum_{i=1}^{N} [(\text{var} \cdot \cos t \cdot \text{vol},) + (\cos t \cdot \text{fixat} \cdot B_t)] + I_c
\]

(3)

Results and Discussion

Using the above methodology and materials it was established the soil erosion and its influence on the development of road network

The role of plots’ positioning was to observe the homogeneous areas in order to create a mapping of the whole area. Thus, plots 1 and 2 have been positioned on the pasture land. Plot number 3 has been positioned in a transition area with unhealthy forest and high slope. The fifth plot has been positioned in a rare forest but with a lower slope (Figure 3). The plots 6,7 and 8 where positioned on morphological criteria due to the fact that the vegetation type was the same.

On the basis of terrain observations referring to the bedrock and erosion indexes, the eight testing plots have been characterized from the terrain erosion point of view. Plot number 6 has received the maximum value, having a very high degree of erosion and 3 plots were quantified with lowest erosional index value (plots number 4,5 and 7).

Table 2. Erosional index value and position for each sample plot

<table>
<thead>
<tr>
<th>Plot Id</th>
<th>Erosional index value</th>
<th>GPS accuracy (absolute value m)</th>
<th>GPS longitude</th>
<th>GPS latitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>7</td>
<td>3</td>
<td>25.82004118</td>
<td>45.53230547</td>
</tr>
<tr>
<td>2</td>
<td>8</td>
<td>3</td>
<td>25.82028269</td>
<td>45.53119449</td>
</tr>
<tr>
<td>3</td>
<td>9</td>
<td>4</td>
<td>25.82252398</td>
<td>45.5286827</td>
</tr>
<tr>
<td>4</td>
<td>6</td>
<td>5</td>
<td>25.82434985</td>
<td>45.52959081</td>
</tr>
<tr>
<td>5</td>
<td>6</td>
<td>4</td>
<td>25.82655249</td>
<td>45.53042163</td>
</tr>
<tr>
<td>6</td>
<td>10</td>
<td>6</td>
<td>25.83178859</td>
<td>45.52844118</td>
</tr>
<tr>
<td>7</td>
<td>6</td>
<td>4</td>
<td>25.83327634</td>
<td>45.53032502</td>
</tr>
<tr>
<td>8</td>
<td>7</td>
<td>4</td>
<td>25.83538237</td>
<td>45.53208327</td>
</tr>
</tbody>
</table>

All of the testing plots are predisposed to erosion because of the geological bedrock structured in this perimeter in two areas: the first one characterized with a highly disposed for erosion bedrock and the other one which consists of more clay than the previous one.

After the download of the point form the GPS Garmin 60CSx, we have put to each one the index’s value into an attribute field which shows the erosion degree from that area.

The establishment of erosion influence areas over the roads network

Knowing the position of the eight points and attributing all the points with the erosion degree and using the SAGA program, based on other studies (Goovaerts, 1997; Bayraktar and Turalioglu, 2005) it was used an ordinary Kriging method the interpolation of these points. Thus, an erosion raster grid resulted. This grid was composed out of cells and each cell has an index which shows the cell’s erosion degree. This has been determined through linear interpolation (Figure 4.).

Figure 4. Grid representation of the interpolated data

As a result of applying “Thiessen Polygons” specific SAGA module (developed by O. Conrad) based on the Nearest Neighbor Method, we were able to determine both the high erosion degree areas and those with less erosion
degree. This SAGA module described Thiessen polygons which represent the specific areas where some points’ influences could be felt (Figure 5.).

Thus, the grid was regrouped and the cells gathered around the testing plots took over the plot’s index. It can be obviously seen that for a better erosion plot description it is necessary to create more testing plots.

The SAGA exported polygons on the basis of Thiessen polygons describe the area and the perimeter which is a very important thing in exactly establishing the area distribution on erosion. This percent can be used in the network development without any erosion risks or increasing erosion predisposal. (Figure 6.)

The most suitable area to develop the network, after drawing the polygons is the blue one which presents the sixth index’s value as shown in the previous image (Figure 5).

In the western side, the other areas are influenced by the lack of forest vegetation and building a road would lead to an erosion increase, especially in an area with an erosion predisposed layer. In the eastern side the slope has influenced the index’s value. The highest values were recorded in the southern side.

Since the aim of methodology is to minimize to reach the optimum solution, the roads which go through areas with high erosion risk must be excluded. Using the GIS, which can work on a cell level (in raster) and is able to generate the shortest roads and with the help of Network 2000 (by applying formula 3 to quantify in the erosion index) one can choose the most convenient ways.

In order to simulate into the Network 2000 without any access to the program script, we have inserted in the areas with high erosion risk, higher values for cost_var and fixed_cost in the Link Editor (a submenu of NETWORK 2000 software) (Figure 7.)
Based on data presented above, the program created connections between sample plots, dividing the proposed road into segments (Figure 8.)

Using this method the program has generated using each segment the most suitable ways of developing the road (Figure 8.). The results of the method underlined that the safest route from this proposed road taking into consideration the erosion index was the route between 3, 4 and 5.

Based on this calculus the road planner can take into consideration it the project the segments of roads with erosional class.
Conclusions

The results indicated in this article show a methodology that transforms punctual readings from the field into distributed information using GIS techniques like reprojection and interpolation. With this information it was possible to create expressive maps for road planners to take better decisions compared to actual Romanian standards in network development according to environmental impact assessment for wood harvesting. Knowing erosional areas from the road network helps both the road planner in developing the network and the road administrator in maintaining the road suitable for harvest activities.

With this study it has been proven that using Geographic Informational Systems to incorporate complex information the road planners has the possibility to create large databases with primary data that can use derived information (as presented in this work) to improve the decisional process. It has been validated the entire data flow from taking punctual data from the field to establishing erosional classes on road segments.

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Agricultural Land use in the Krekenava Regional Park and Naujamiestis Subdistrict

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2Aleksandras Stulginskis University

Abstract

Analysis of the declared agricultural land and crop areas situated in the Krekenava regional park, which is situated in the Middle Lithuania, is presented in the article. Almost the entire territory of the park is situated in Panevėžys district, only the south-western edge marginally intervenes into the Kėdainiai district municipality of Kaunas County. The Naujamiestis subdistrict was chosen for the comparison of the use of agricultural lands in the regional park.

The area of the subdistrict covers 15.6 thousand ha. In 2011, the total agricultural land and crop area declared in the regional park was 8184.19 ha, i.e. larger by 2510.31 ha or 30.67 percent more than in 2008. 371 family farms were declared, i.e. by 100 farms more in comparison with 2008.

In 2011, in the Naujamiestis subdistrict the declared area of agricultural lands was 9851.33 ha, i.e. larger by 994.94 ha or 10.1 percent more than in 2008. The number of declared farmers in 2011 was 329, i.e. by 43 farms or 13 percent more than in 2008. Increased area of declared land and number of farms had and impact on changes in declared crops structure as well. Almost all declared crops area in both regional parks increased, except leguminous crops, which declared area decreased a lot. Only very small area of declared land did not meet requirements of good farming practice and rules of declaration in analyzed years.

Comparison of declared areas in the Krekenava regional park, the Naujamiestis subdistrict and the municipality of Panevėžys district showed that agricultural lands and crop structure in the arable land is very similar – larger land areas are used for the growth of spring and winter crops. Consequently, the regulation of the activity, carried out in the Krekenava regional park, has no influence upon the intensity of land use.

Key words: protected areas, regional park, land use, agricultural lands, farming activity, declared areas.

Introduction

Lithuania is historically an agricultural country. The agricultural sector plays a very important economic, social, environmental, ethnic and cultural function and is considered a priority for the country’s agricultural industry (Čiegis et al. 2008).

Farming in protected areas is difficult, because faced with environmental and economic problems. Protected areas are divided into zones, which are subject to different restrictions of economic activity, and therefore economic activity differs as well.

The aim of protected areas is to conserve natural habitats and species (common on agricultural land) of the European Community interest. Such rate of the conservation and use of treatment of the territory is determined, that non-intensive farming, forming natural values, should not be interrupted and should be continued in environmentally-friendly manner. If the extensive farming will disappear in natural grasslands, pastures and wetlands, such areas will overgrow with shrubs, trees and biodiversity would face the biggest threat. As a result, only those activities are limited which could suddenly and irreversibly destroy natural values, for example, grassland ploughing, drainage works, liming, fertilizer and so on.

The Lithuanian Rural Development Programme 2007-2013 (Lietuvos 2007) provides that farmers enjoying only minimum insurance requirements set in the protected area regulations (not to plough grasslands, not dry them, not use fertilizers, liming materials and so on.) receive additional compensation for each hectare of declared agricultural land every year (together with the EU direct payments paid by the normal manner).

Sustainable development in agriculture – is an organic farming helping solve important problems in rural areas (Brazauskienė 2002).

Organic farming is recognized as a sustainable agriculture and is an important expression of its potential options to address the competitiveness of agricultural products, rural employment and additional income issues and work together as a preventive environmental measure (Offermanns et al. 2000).

After the assessment of the increasingly popular concepts of sustainable farming development in Lithuania, the following scientific problems are singled out (Kripitis 2009):
- sustainable farm management system is not sufficiently explored (in terms of management), there is not enough systematic and strategic research on this subject;
- development of sustainable farming is more examined as a conservation management tool rather than as a viable farming system;
- economic problems are that the government financial support mechanism is not scientifically substantiated for sustainable farm management as a system of support coincided with the traditional farming system management;
- the regulatory problems occur in the fact that sustainable farming management system should not legitimize the state level, sustainable farming management system is not established;
- sustainable farming management system is not sufficiently promoted as part of sustainable development, ensuring sustainable environment-friendly management systems implementation.
Protected areas are necessary to comply with the principles of sustainable farming, expansion of area under organic farming and organic farming for measures to preserve the landscape, the importance of biodiversity, natural and cultural heritage values (Ivavičiūtė et. al. 2010).

**The object of the investigation.** Agricultural lands in the Krekenava regional park and the Naujamiestis subdistrict.

**The aim of the investigation.** To carry out the comparative analysis of the years 2008 and 2011 (as well as the one of the declared areas for which direct payments are paid) of the agricultural lands situated in the Krekenava regional park and the Naujamiestis subdistrict.

**Tasks of the investigation:**
1. To characterize the Krekenava regional park.
2. To carry out the analysis of the declared agricultural lands in the Krekenava regional park and the Naujamiestis subdistrict.
3. To analyze the declared areas situated in the regional park and the subdistrict, for which direct payments are being paid.

**Methodology of research**

Comparative, analytical as well as statistical and logical analysis methods were used for the investigation of the years 2008 and 2011. The analysis of the agricultural lands in the Krekenava regional park and the Naujamiestis subdistrict was carried out following the data of the Agriculture Information and Rural Business Center on the declared agricultural land and crop areas.

The survey was conducted to determine whether agricultural land use and environmental measures for the Krekenava regional park and the Naujamiestis subdistrict differ because of the restrictions and recommendations (on the regional parks) to protect and enhance biodiversity, promote environmentally friendly farming methods and organic farming measures.

**Description of the Krekenava Regional Park**

The Krekenava Regional Park was founded on September 24, 1992 following the decision “Concerning the establishment of regional parks and reserves” to preserve the landscape of the Nevėžis river valley, its natural ecosystem and cultural heritage treasures, to look after them and use rationally.

Almost the entire park’s territory is situated in the Panevėžys district municipality of Panevėžys County, only the south-western edge marginally intervenes into the Kėdainiai district municipality of Kaunas County.

The Nevėžis old valley is the biggest treasure of Middle Lithuanian Lowland landscape. A lot of traces of the old riverbeds appeared when the river changed its course. In the time of tides the River Nevėžis bursts from its banks and in the flooded bank meadows it leaves a lot of silt and forms a lot of irregularly-shaped pools and ponds. The landscape of the Nevėžis old valley is little touched by man and is a heritage of the post ice-age times. The Nevėžis Middle River Reserve is founded to preserve the treasures of nature and landscape.

Natural treasures are abundant in the forests of the park as well. Old oak forests, soaked swampy woods, even small groves surrounded by arable land are the home for numerous plants and animals. Butterworts, northern firmoss and Lady's Slipper orchids flourish in the forests. In the old oak forests rare beetles can be found such as flower chafers.

Having evaluated the location of Lithuanian regional parks one can see that Middle Lithuania has only one regional park, i.e. the Krekenava regional park, therefore, the significance of this park is especially important.

Having prepared the plan of the Krekenava regional park and its zones in 2009 and having evaluated the character and distribution of cultural heritage, the following zones were singled out: conservation, ecological protection, recreational, economic and residential priority zones. The change of areas was predicted as well (Krekenavos 2009). Having carried out the analysis of the change of regional park’s areas one can see that the area of the park has decreased from 111749.0 ha up to 11589.7 ha, i.e. by 159.4 ha or by 1.4 percent, respectively. The conservation priority zone was reduced most of all (by 2.5 percent), the ecological protection priority zone was increased by 1.9 percent. The agricultural zone has increased by 36.8 ha or by 0.7 percent, respectively.

**The average productivity of soils of agricultural lands in the Panevėžys district municipality is 47.5 scores**

Panevėžys district is situated in the zone of Central Lithuania and belongs to the zone of soils with average fertility of II B-1 district group, for use in the main commercial agricultural crops, i.e. winter wheat, barley, rape, flax, sugar beet (Mažvila et. al. 2010).

Comparing with the average productivity of agricultural lands of the Panevėžys district municipality, which is 45.6 scores, the average productivity of agricultural lands in the Kėdainiai district municipality is higher.

Agricultural farming lands in the Panevėžys district municipality make up 124 980.15 ha or 25.94 percent of the total district’s area and according to the peculiarities of economic exploitation they distribute in the following way: arable land – 115 322.36 ha (92.27 percent), orchards – 1837.79 ha (1.48 percent), meadows and natural pastures – 7 820.00 ha (6.25 percent) (Lietuvos 2011).
Agricultural lands make up 33.0 percent of the Krekenava regional park’s territory (Raudonytė 2009) (Fig.1). The average productivity of the agricultural lands situated in the park is higher than 45 scores.

The largest part of agricultural lands is covered by forests (43.0 percent). Moist, mainly mixed forests, in some places oak-woods and ash-woods, predominate in the Krekenava regional park (Krekenavos 2011).

The analysis of the declared areas of agricultural lands in the Krekenava regional park and Naujamiestis subdistrict

In 2009, Lithuanian farmers and legal entities used and declared 2420 thousand ha of agricultural lands, private agricultural land users and small landowners – 220 thousand ha, the members of the community gardeners – 16 thousand hectares (Mažvila et. al. 2010).

Following the data of the Agriculture Information and Rural Business Center the declared area of agricultural lands and crops occupied 5673.88 ha in 2008, it made up 48.96 percent of the total regional park’s area. The number of the farmers, who had declared their farming lands, was 271. The average area of the declared farms was 20.94 ha.

In 2011, the total agricultural land and crop area declared in the regional park was 8184.19 ha (Fig. 2), i.e. larger by 2510.31 ha or 30.67 percent more than in 2008. 371 family farms were declared, i.e. by 100 farms more in comparison with 2008.

The Naujamiestis subdistrict was chosen for the comparison of the use of agricultural lands in the Naujamiestis subdistrict and the regional park. The territory covered the area of approximately 6 thousand ha. There were 66 villages, 4 agricultural companies and agricultural cooperatives in the subdistrict (Naujamiesčio 2011).

In 2008, the declared area of agricultural lands in Naujamiestis subdistrict covered 8856.39 ha and it made up 56.77 percent of the total subdistrict’s area. 286 farmers introduced declarations. The average area of the declared farms was 30.97 ha.

In 2011, the declared area of the agricultural lands was 9851.33 ha i.e. larger by 994.94 ha or 10.1 percent more than in 2008. The number of declared farmers in 2011 was 329, i.e. more by 43 farms or more by 13 percent than in 2008.

The above analysis suggests that, compared with 2011 in 2008, the number of declared farms increased (in the Krekenava regional park – by 27 percent, in the Naujamiestis subdistrict – by 13 percent), and the declared areas increased in the Krekenava regional park – by 30.67 percent, in the Naujamiestis subdistrict – by 10.1 percent, respectively.

Comparing the data received from Krekenava regional park and the municipality of Panevėžys district over the declared areas of agricultural lands one can see that the crop structure in the arable land is very similar – larger land areas are used for the growth of crops (Fig. 2). Consequently, the regulation of the activity carried out in the Krekenava regional park does not have influence upon the intensity of land use.
Having conducted the analysis of grain-producing areas of the Panevėžys district municipalities, the Krekenava regional park and the Naujamiestis subdistrict we found that summer crops were the most popular and they made up more than 60 percent of the total cereal area in the Krekenava regional park, leguminous crops were the least popular (in the Krekenava regional park – 51.26 ha, in the Naujamiestis subdistrict – 223.36 ha) (Fig. 3).

Figure 3. Distribution of the declared crop areas in 2011 in the Krekenava regional park, Naujamiestis subdistrict and the Panevėžys district municipality, in percent (Data Source: The Agriculture and Rural business information center)

In comparison with 2008, the Krekenava regional park winter cereal area has increased by 8.96 percent, spring – 48.17 percent, but leguminous crops decreased by 39.2 percent. The Naujamiestis subdistrict winter cereal area has increased by 2.9 percent, spring cereals – 15.36 percent, leguminous crop areas, as well as in the Krekenava regional park, fell by 45.56 percent. (table 1).

Table 1. Cereal area ha in the Krekenava regional park and the Naujamiestis subdistrict in 2008 and 2011, in ha
(Data Source: The Agriculture and Rural business information center)

<table>
<thead>
<tr>
<th>Cereals</th>
<th>The area of the Krekenava RP in 2011, ha</th>
<th>The area of the Naujamiestis subdistrict in 2011, ha</th>
<th>The area of the Krekenava RP in 2008, ha</th>
<th>The area of the Naujamiestis subdistrict in 2008, ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Winter cereals</td>
<td>1597.62</td>
<td>2305.14</td>
<td>1454.3</td>
<td>2238.51</td>
</tr>
<tr>
<td>Spring cereals</td>
<td>2537.25</td>
<td>3265.39</td>
<td>1315.08</td>
<td>2763.89</td>
</tr>
<tr>
<td>Leguminous crops</td>
<td>51.26</td>
<td>223.36</td>
<td>84.3</td>
<td>410.28</td>
</tr>
<tr>
<td>Total, in ha</td>
<td>4186.13</td>
<td>5793.89</td>
<td>2853.68</td>
<td>5412.68</td>
</tr>
</tbody>
</table>

The changes of the technical plant areas are seen in Figure 4. Thus, in the Krekenava regional park, this area has increased by 38.23 percent, in the Naujamiestis subdistrict – by 27.35 percent. Compared to 2011, we received that the Krekenava regional park technical plant area is 5.5 percent higher.

Figure 4. Technical plant areas declared in the Krekenava regional park and the Naujamiestis subdistrict, in ha
(Data Source: The Agriculture and Rural business information center)

Comparing potato and vegetable areas of 2008 and 2011 we found out that they increased by 52.48 percent in the Krekenava Regional Park and in the Naujamiestis subdistrict – by 30.62 percent (Fig. 5). The Krekenava regional park potato and vegetable area made up 2.62 percent of the total agricultural land and crop area, the Naujamiestis subdistrict –1.66 percent.
Declared areas of orchards and berry plantations increased by 11.93 hectares in the regional park, but in the analyzed subdistrict declined by 0.82 hectares (Fig. 6). The analysis of declared agricultural land and crop structure revealed that in the park orchards and berry plantations made up 0.23 percent in 2011, in the subdistrict – 1.08 percent.

The carried out analysis of the declared data of 2008 and 2011 shows that the areas of grasslands and pastures increased both in the Krekenava RP (25.42 percent) and in the Naujamiestis subdistrict (22.13 percent) (Fig. 7) and in 2011 made up 18.19 percent of the total agricultural land and crop area in the regional park, and 16.17 percent in the subdistrict.

Currently, grassland and pasture areas in the regional park are distributed as follows: pastures - grasslands under 5 years make up 63.9 percent, perennials (5 years and more) – 25.57 percent of the total declared pastures and grasslands area. In the Naujamiestis subdistrict areas are distributed evenly: pastures - grasslands under 5 years make up 41.24 percent, perennials – 42.08 percent. Thus, grasslands - pastures under 5 years dominate in the Krekenava regional park.

Payments for declared areas

In the Krekenava regional park, 271 holding of the farmer declared 5673.88 hectares of agricultural land and crop land in 2008. Direct payments were paid to 271 farms for 5668.16 ha, i.e. 99.90 percent of the total area

14 farmers were not paid direct payments for the area of 5.72 ha, i.e. for 0.10 percent of the total area claimed.
In 2011, 329 farming households declared 8170.33 hectares of agricultural land and crop land. 370 farmers received direct payments to farms in the area of 8170.33 hectares or 99.83 percent of the total area claimed. 35 households received benefits for the 13.86 hectares and it is 0.17 percent of the declared area. The assessment of the data of 2008 and 2011 (expressed in percentage) shows that in 2011 the number of farms and the area for which the direct payments were not received has increased.

In 2008, from 286 farmers living in the Naujamiestis subdistrict (who had declared areas) direct payments were paid for the area of 8855.1 ha, i.e. 99.99 per cent from the total declared area (8856.39 ha). 19 farmers do not receive direct payments for the area of 1.29 ha (0.01 percent).

In 2011, from 329 farmers (who had declared areas) direct payments were paid for the area of 9849.54 ha, i.e. 99.98 per cent from the total declared area (9851.33 ha). 25 farmers did not receive direct payments for the area of 1.79 ha (0.02 percent).

After the comparison of the declared data of the Krekenava regional park and the Naujamiestis subdistrict on the not paid direct payments we received that in the Regional Park there were more farms, which did not receive the direct payments (9.43 percent) (in comparison with the Naujamiestis subdistrict (7.6 percent)). Areas for which direct payments were not paid were larger in the park (0.17 percent) (in comparison with the Naujamiestis subdistrict (0.02 percent)).

In the Krekenava regional park, only 2 farmers (from 271) applied measures of organic farming in the area of 31.76 ha in 2008 and it made up 0.56 percent from the total declared area. 3 farmers were occupied in ecological farming, and the total area of ecological farms were almost 40.66 ha (0.72 percent from the total declared area and 0.80 percent from the declared agricultural land area).

In 2011, 7 farmers applied organic means in the area of 140.29 hectares, which made up 1.71 percent of the total area claimed. The data analysis shows that the number of farms and area has increased in 2011 (77.36 percent from the area in which the organic farming means were applied).

In 2008, 10 farmers applied organic means in the Naujamiestis subdistrict in the area of 642.72 ha (3.5 percent of all who had declared crops), it makes up 7.26 per cent from the total area claimed.

In 2011, the above measures were applied by 12 farmers (3.65 percent) in the area of 852.67 hectares (8.66 percent). Comparing 2008 and 2011 it was revealed that the area, in which organic means had been applied, increased by 24.62 percent in the Naujamiestis subdistrict.

The carried out analysis shows that in the Krekenava regional park both in 2008 and 2011 environmental measures have been applied in the smaller declared area than that in the subdistrict. In 2011, these areas covered 1.7 percent of the regional park, and in the subdistrict – 8.66 percent of the total area claimed.

In 2008, 12 farmers farmed in Krekenava regional park in the area of 22.42 ha of the Natura 2000 territory. In 2011, 10 farmers farmed in the regional park in the area of 20.63 ha of the Natura 2000 territory. Thus, although the area declared in 2011 had increased, but the number of farms and the area within that territory decreased.

In 2008, in the Naujamiestis subdistrict one farmer's existing 2.27 hectare property was included into the Natura 2000 site. Two family farms occupying 4.04 hectares were declared in 2011.

In 2008, in the Naujamiestis subdistrict, the total area of low disadvantage occupied 166.84 ha (1.88 percent from the total area claimed), the number of farmers – 7. In 2011, 12 households declared the 276.12 ha of low disadvantage areas.

Meanwhile, in the Krekenava regional park the areas of low disadvantage were unreported neither in 2008 nor in 2011.

Support recipients farming in the park get payments for the declared areas according to the measure „Landscape management” of the Lithuanian rural development program for 2007-2013 (Lietuvos 2007).

In 2008, in the field of activity „The management of natural and semi-natural meadows” the area of 22.07 ha was declared (0.39 percent of the total agricultural land area, for which direct payments are paid). The declared area in Naujamiestis subdistrict (in the above mentioned field) was 22.37 ha (0.25 percent).

In 2011, these areas almost doubled. The Krekenava regional park declared 41.15 hectares (0.5 percent the total agricultural land area, for which direct payments are paid), in the subdistrict - 37.95 hectares or 0.39 percent.

In 2008 and 2011, the area of 0.1 ha was declared in the Krekenava regional park, for which direct payments are being paid according to the program „Improvement of the condition of risky water reservoirs”, activity field – „The management of the protective strip of water reservoirs” shores in meadows (compulsory strip)’.

According to the activity field „Stubble fields in winter” the total area of 258.28 ha was declared in the Krekenava regional park. Barley (spring, non-malted) and their stubble (125.26 ha or 48.5 percent) occupy the largest area. Malted barley and their stubble make up 10.83 percent from the total declared area (according to the above-mentioned field activity). Winter triticale and their stubble cover 37.48 ha or 14.5 percent, the areas of spring triticale and their stubble were not declared. The areas of declared rape and their stubble distribute in the following way: winter rape make up 16.07 per cent or 41.5 ha, spring rape – 10.1 per cent or 26.08 ha.

In 2011, in the regional park under the heading "Stubble fields in winter," the general area declared was 419.24 hectares, of which the largest area was occupied by wheat and its stubble (281.73 hectares or 67.19 percent.). In 2008 the areas of wheat and their stubble were not declared.

In 2008, payments received according to the activity field „Stubble fields in winter” by the farmers from the subdistrict distribute in a different way when comparing with the Krekenava regional park. Here, the largest are is occupied by declared rape and their stubble, spring rape make up 58.96 per cent, winter rape – 19.46 percent.
In the Naujamiestis subdistrict payments for the declared barley and their stubble areas are also paid. They distribute in the following way: malted barley – 6.92 ha or 2.58 per cent, spring, non-malted barley – 1.1 ha or 0.41 per cent.

In 2011, in the subdistrict, as in the analyzed park, wheat and stubble area have been declared the most (221.9 hectares or 75.29 percent from the declared "Stubble fields in winter" area). Meanwhile, in 2008, the area of 49.77 hectares or 18.59 percent was declared.

In 2008, the declared areas in the Krekenava regional park (according to the measure „The first afforestation of the land designated for agricultural purposes“ of the Lithuanian rural development program for 2007-2013) was distributed in the following way: conifers and (or) soft deciduous trees with the impurity of not less than 20 percent of hard deciduous trees and (or) lime-trees (4.17 ha). In 2011, the area of 8.48 hectares was declared.

In the Naujamiestis subdistrict, the areas according to the above-mentioned measures were not declared.

The ecological farming, afforestation and the expansion of woodiness in protected areas as well as others environment protection measures are very important factors for environment protection, ecological landscape, preservation of cultural heritage when evaluating such aspects as the rational use of agricultural lands and other ecological, social and economical functions.

**Conclusions**

Comparing 2011 and 2008, the number of declared farms increased (in the Krekenava regional park – by 27 percent, in the Naujamiestis subdistrict – by 13 percent.), and the declared area increased in the Krekenava regional park and in the Naujamiestis subdistrict by 30.67 percent and 10.1 percent, respectively.

Increased area of declared land and number of farms had and impact on changes in declared crops structure as well. 2011 and 2008, the winter cereal area in the Krekenava regional park has increased by 8.96 percent, spring – 48.17 percent, but leguminous crops decreased by 39.2 percent. The winter cereal areas in the Naujamiestis subdistrict increased by 2.9 percent, spring cereals – 15.36 percent, leguminous crop areas, as well as in the Krekenava regional park, fell by 45.56 percent.

Technical plant areas in the Krekenava regional park area increased by 38.23 percent, the Naujamiestis subdistrict area increased by 27.35 percent. Potato and vegetable areas compared to 2008 and 2011 increased by 52.48 percent in the regional park and in the subdistrict – 30.62 percent. Analysis of declared data in 2008 and 2011 shows that the areas of grasslands and pastures increased both in the Krekenava regional park (25.42 percent) and the Naujamiestis subdistrict (22.13 percent) and in 2011 made up 18.19 percent of the regional park, and 16.17 percent of the subdistrict’s agricultural land and crop area.

Having compared the data of the Krekenava regional park, the Naujamiestis subdistrict and the municipality of Panevėžys district over the declared areas of agricultural lands it was received that the agricultural lands and crop structure in the arable land is very similar – larger land areas are used for the growth of spring and winter crops. Consequently, the regulation of the activity, carried out in the Krekenava regional park, has no influence upon the intensity of land use.

Direct payments were paid to 271 farms for 5668.16 ha in the Krekenava regional park in 2008, i.e. 99.90 percent of the total area declared, in 2011 – to 370 family farms for 8170.33 ha (99.83 percent). Direct payments were paid to 286 households for the 8855.1 hectares in the Naujamiestis subdistrict in 2008, i.e. 99.99 percent. In 2011, 329 farmers received payments for 9849.54 hectares, i.e. 99.99 percent. This data shows that there is only very small area of declared land, in analyzed areas which did not meet requirements of good farming practice and rules of declaration.

It is recommended to develop animal-breeding as well as ecological farming for the improvement of the condition of environment and landscape in Krekenava regional park. It is necessary to form clear and sufficient policy over the compensation for the restrictions of the farming in protected areas, which should reduce the load of ordinary economic activity in protected areas, and their usage should become more favorable for protected valuables.

**References**


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Soil Water Dynamics During the Periods Without Precipitation for Crop Management at the Farm Level

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Abstract

Soil moisture is important circumstance for soil utilization in the agricultural plant production. The great impact on the production is during the drought periods. We prepared the forecast for the soil moisture for the next short period. The decrease trend of volumetric soil water content was observed during the dry season of 30 days with the rainfall up to 3 mm in 2009 and 2010; 8.9.-8.10.2009 (30 days) and 23.6.-22.7.2010 (29 days) in Bocegaj subcatchment, Slovakia. The dynamics vary between the places we observed and the depth. The highest decrease was at the depth of 300 mm, the lowest at the depth of 1000 mm. The differences reached mainly up to 10 percent of volume (average 4.3 % vol.) in 2009 and over 15 percent of volume (average 13.3 % vol.) in 2010. The higher temperature, the soil type, the texture and the different crops influenced the recession of the soil moisture in 2010. The soil dynamics at the farm territory is a primary factor for the crop management and the farm economics. The new measurement devices can help us to evaluate the soil water conditions.

Keywords: drought, soil water, soil moisture, crop management

Introduction

The landscape structure is being changed, as well as the processes connected with the landscape. One of these processes is the water cycle. Knowledge of the soil water content and its dynamics is significant, especially for farmers. They might be able to react in time to avoid the lack of water influenced by atmosphere interaction (WMO, 2008). The soil moisture should be measured at a most representative location of a watershed when the climatic data or the vegetative conditions indicate a likelihood of the actual conditions (NRCS, 2009).

Rainfall and snowmelt are the natural sources of the soil water and are usually enormously reduced during drought. The slope shape, gradient, and the roughness of the soil surface will affect the soil water content meanwhile surface or subsurface run-off from the adjacent upslope sites can be added to the soil moisture, while surface runoff can remove water from a site. Evaporation, plant transpiration and the deep percolation beyond the rooting depth are the other factors that deplete the soil moisture (NRCS, 2009).

Soil water, an integral part of the hydrologic cycle and water balance, for a given time period (t):

\[ \frac{\partial S}{\partial t} = P - ET - Ro - Dr \]  

where \( \partial S/\partial t \), P, ET, Ro, and Dr are the change in soil water, precipitation, evapotranspiration (ET), runoff and drainage for the same time period \( t \) in Equation (1). The soil water (S) is the equivalent depth of water:

\[ S = \theta \cdot \Delta d \]  

where \( \theta \) is the average volumetric water content of the soil over a layer of soil and \( \Delta d \) is the thickness of the soil layer in Equation (2). Neglecting drainage and assuming runoff follows an appropriate soil conservation service (SCS) curve for a given soil type (Dingman, 2008), and soil water measurements reflect how effective a rainfall event was at replenishing a soil profile (Hunt, 2009).

Climate change represents a major threat in relation to water scarcity and droughts, particularly in the Mediterranean, Central and the Eastern Europe, with predictions that both scarcity and the droughts will increase and therefore, the water resource management decisions might be more difficult. The considerable uncertainties remain, however, not only in the extent and nature of the possible impacts but also in the potential efficacy of the adaptation measures. Drought is a temporary aberration within the natural variability and can be considered an unpredictable hazard of nature; it differs from aridity which is a long-term, average feature of climate (EUWI, 2007). It is often difficult to predict when a drought arises. Likewise, it is also difficult to determine when the drought disappears and what kind of measurements should be taken. Intensity refers to the degree of the precipitation shortfall and/or the severity of the impacts associated with the shortfall (WMO, 2006).

Drought is a natural, reoccurring, worldwide phenomenon that is responsible for widespread losses in agriculture and other sectors (Hunt, 2009). Some of the most common drought definitions are summarised in Tate & Gustard (2000).

Drought studies have been suffering from the lack of consistent methods for drought analysis. The first step in a drought analysis would be to define the drought event. Scientists have only agreed on very general definitions of a drought, e.g. Beran & Rodier (1985): “The chief characteristic of a drought is a decrease of water availability in a particular period over a particular area”.

Droughts are commonly classified by type as meteorological, agricultural, hydrological and socioeconomic phenomena. Meteorological drought is usually defined by a precipitation deficiency threshold over a predetermined period of time. Agricultural drought is defined more commonly by the availability of soil water to support crop and forage growth than by the departure of normal precipitation over some specified period of time. Hydrological drought is
even further removed from the precipitation deficiency since it is normally defined by the departure of surface and subsurface water supplies from some average condition at various points at the time. Socio-economic drought differs markedly from the other types of drought because it reflects the relationship between the supply and demand for some commodity or economic good, such as water, livestock forage or hydroelectric power that is dependent on precipitation (WMO, 2006; EUWI, 2007).

Wilhite and Glantz (1985) labelled meteorological drought as a prolonged period of dry weather and precipitation deficits. Agricultural drought was defined as a combination of short-term precipitation shortages and increased ET demands from high-temperature anomalies that lead to adverse agricultural impacts.

Each drought produces a unique set of impacts, depending not only on its severity, duration, and spatial extent but also on ever-changing social conditions. Society’s vulnerability to drought is determined by a wide range of factors, both physical and social, such as demographic trends and geographic characteristics. One of the challenges of planning for drought understands its impacts, both direct and indirect. In the last few decades, interest in planning for drought has increased at all levels (Monacelli, 2005).

The aim of article is to show the dynamics of the soil moisture in an arable soil up to 1 m depth in the subcatchment Bocegaj during the period without precipitation in the years 2009 and 2010. During the year 2011 the measurement equipment and methodology was change, therefore we present just a part of the results.

Materials and methods

The area of interest is a subcatchment of the Bocegaj stream with an area of 9.75 square kilometres (Figure 1). It is situated in Southeast Slovakia, approximately 10 kilometres northeast of Nitra. Daily average air temperature is 9.8 °C (average value for the years 1961-1990) in the Nitra region, and total yearly precipitation is 539 millimetres (average value for the years 1961-1990). Soil types are mainly represented by Haplic Luvisol (52 percent of arable soil), Cambisols (37.5 percent) and Fluvisols (10.5 percent). Soil texture groups are represented by loam top soil and clay loam subsoil (62.1 percent of arable soil), clay loam (15.3 percent), loam (7.5 percent), and sandy loam soils (15.1 percent). According to information from hydrogeologists, the relatively confined aquifer is quite variable under the terrain, ranging approximately from 2 to 12 metres. The same situation exists with ground water level. The area of interest is presented particularly in Kaletova work (2011).

The soil moisture by volume was monitored from the 8th September 2009 to the 24th November 2010 at a depth of 1 meter in the 5 observation places. The measurements were done every fortnight. The soil moisture was measured by the Profile Probe PR2/6 (Delta-T Device Ltd.) with connection to the Moisture Meter HH2 (Delta-T Device Ltd.). The Profile Probe PR2/6 uses frequency domain reflectometry to measure volumetric soil moisture. The observation places were constructed on the edge of the arable soil cross the area to be protected from the possible damage caused by farmers.

Two seasons with the total rainfall up to 3 mm were chosen; from the 8th September to 8th October 2009 (30 days) and from the 23rd June to 22nd July 2010 (29 days). We assumed that rainfalls up to 3 mm were intercepted on the vegetation.

Figure 1. Bocegaj subcatchment area within the Slovakia and points of measurements
Results and discussion

The measured values of the volumetric soil water content in the percentage of volume are shown in the figure 2 in depths 100, 200, 300, 400, 600 and 1000 mm. The figure shows only the period without precipitations up to 3 mm. The figure 3 shows differences in the percentage of volume between minimal and maximal value of the volumetric soil water content during the period.

There is visible decrease trend of the soil moisture during the period without rainfall up to 3 mm in both years. The higher decreases were in the 2010. The key point is that one of the first days of the observation the soil water content was almost equal to the field capacity. There was enough soil water to evaporate, and crops were in the growth (tab. 1). Also, the higher temperature, soil type and texture, and different crops influenced the recession of the soil moisture in 2010.

Table 1. Crops grown around the observation places

<table>
<thead>
<tr>
<th>Place</th>
<th>2009</th>
<th>2010</th>
<th>Soil</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>after the tillage; Brassica napus was seeded</td>
<td>Brassica napus</td>
<td>Haplic Luvisol, loam</td>
</tr>
<tr>
<td>2</td>
<td>after the tillage; Brassica napus was seeded</td>
<td>Brassica napus</td>
<td>Fluvisols, clay</td>
</tr>
<tr>
<td>3</td>
<td>after the tillage; Triticum aestivum was seeded</td>
<td>Triticum aestivum</td>
<td>Cambisols, loam</td>
</tr>
<tr>
<td>4</td>
<td>Medicago sativa</td>
<td>Medicago sativa</td>
<td>Fluvisols, clay</td>
</tr>
<tr>
<td>5</td>
<td>after the tillage</td>
<td>Cucurbita pepo</td>
<td>Fluvisols, clay</td>
</tr>
</tbody>
</table>

The dynamics vary between the observation places and depth (fig. 2-6). The highest decrease was up to 300 mm depth, the lowest in the depth of 1000 mm. In the literature (e.g. Dub, 1963) it is written that by the influence of evapotranspiration, arable soil during the dry season is dried up only in the upper layer up to the depth of 150 mm and slightly less in the layer from 150 to 250 mm, the deeper layers dry up very little. The differences were mainly up to 10 percent of volume (average 4.3 % vol.) in 2009. In 2010 the differences were over 15 percent of volume (average 13.3% vol.) (fig. 3).

The volumetric soil water content descended below the wilting point at the end of the observed period in the soil depth of 100 mm in all places. Mainly in 2009 the soil moisture was lower than the wilting point. The wilting point was defined according to the soil type and texture (range 17–23 %).

The decrease of volumetric soil water content in lower depths of the profiles was made by the capillary raise of water into the upper soil layers, water consumed by the plants, and percolation of the soil water into the deeper layers. The ground water level was not observed at the depth of 2 m, therefore the influence on soil moisture by capillary raised ground water is not assumed in these observation places.

Places 1 and 2 were on different soil type, but the grown crop was the same, therefore we could analyse the impact of crop on the dynamic of soil water content. According to fig. 2 and 3, the dynamic is different - the place 1 was dried mainly in the depth up to 400 mm, soil water content in the depths 600 and 1000 mm was almost constant. In place 2 the dynamic was lower, and soil water content was almost constant during the period of observations.

Figure 2. Dynamics of volumetric soil water content (in % vol.) in the different depth in the 1st place
Fig. 3, 5 and 6 shows the dynamics of soil water content in the clay Fluvisols with different crops (tab. 1). In 2009 the measurements were done after the tillage, except the place 4 where during the whole observation period the *Medicago sativa* was grown. All three places had the different dynamics. The second and fifth place had similar dynamic up to 400 mm. The main difference was in the depths 600 and 1000 mm - in the place 2 the decrease trend was in all depths, but in the place 5, the decrease trend in depth 1000 mm was minimal. Also, the soil profile up to 300 mm was dried quicker in place 5 than in place 2.
Figure 5. Dynamics of volumetric soil water content (in % vol.) in the different depth in the 4th place

Figure 6. Dynamics of volumetric soil water content (in % vol.) in the different depth in the 5th place

Figure 7. Differences of the soil moisture in the different depth and place in the 2009 and 2010
Conclusion

Soil-water measurements could have major benefits an important part of the farmer’s economy. Being able to measure soil water and apply soil water observations to alert agricultural producers of developing drought conditions.

New measurement devices are very precise by soil water content estimation.

The decrease trend of the volumetric soil water content was observed during the dry season within 30 days with the rainfall up to 3 mm in 2009 and 2010. The decrease had been influenced particularly by the high air temperature, crops and soil type and texture. The higher decrease occurred in 2010 because of the crops in the soil and the higher air temperature. There is evidently obvious decrease of the soil moisture in the season without rainfall (approximately 2 percent of volume per week in 2009).

Knowing the amount and dynamics of the soil water content we may predict and react in time especially to the current, climatic conditions of the environment. Farmers may determine the date and amount of additional irrigation or apply the other agrotechnical arrangements; water managers may forecast revised water balance for catchment and so on.

The landscape, its structure, and its cover are dramatically changed in the agricultural period of the year and mainly due to the impact of the water cycle on evapotranspiration. Repudiation of the landscape like the part of the cycle is a mistake of majority of the models, and so the results differ in the simulated and measured values.

Acknowledgement. This work was supported by grants No. VEGA 1/0949/11, VEGA 1/0027/12 of the Slovak Scientific Grant Agency.

References

Genetic Diversity of Quercus robur, Quercus petraea and Their Hybrids in Lithuania

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Abstract

Genetic diversity is an integral component of biodiversity. Genetic diversity being a reliable basis in the evolution of forest woody plants has helped forests and woody species to adapt to changing and unfavourable conditions and has contributed to the formation of unique, irreplaceable genetic resources of forest woody plants for thousands of years. Genetic diversity of the seedlings from Pajiesis plantations that are the progenies of Quercus genus in the Trakas forest of Seirijai district of Alytus forest enterprise of Lithuania has been investigated in this paper. All the samples were divided into 6 groups by assignment of female tree and its open pollinated progeny (by prevalence in the family) to any of two oak species or their interspecific hybrid using mainly morphological traits of leaves. Genetic studies were carried out by microsatellite (SSR) and RAPD methods. SSR analysis has showed a 45% lack of heterozygous genotypes for only one of the groups being investigated, where a parent tree (♀) is Q. robur, while its progeny in the next generation is (F₁) hybrid. The obtained genetic differentiation coefficient (Fₛ) between families ranged from 13.8% to 51.6%. The comparison of six groups as independent units (without division into families) showed a significant increase of inbreeding coefficient (Fᵢ) up to 0.2595, while genetic differentiation coefficient (Fₛ) decreased and amounted to 8.4%. RAPD analysis has revealed that the total genetic diversity (Hₛ) ranged from 0.2673 to 0.5170 and in all the cases was higher than genetic diversity within groups (Hᵢ). It shows that variability of genetic differences between the groups amounts to 11-13%, whereas variability in other groups amounts to only 4-6%. Genetic differentiation coefficient (Gₛ) which estimates the part of gene diversity spread between the groups ranges from 16.8% to 44.8%.

Introduction

According to the Convention on Biological Diversity, convened at the time of the United Nations Conference in Rio de Janeiro on 5 June 1992, biodiversity means the variability among living organisms from all sources, including inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems. Genetic diversity is an integral component of biodiversity. Genetic diversity is the basis of adaptability and thereby the basis of species survival. It is significant for ecological, economic and ethical reasons.

Genetic diversity being a reliable basis in the evolution of forest woody plants has helped forests and woody species to adapt to changing and unfavourable conditions and has contributed to the formation of unique, irreplaceable genetic resources of forest woody plants for thousands of years (Jurkevič et al. 1977, Altuchova 2004). Today the main purpose of the preservation of forest genetic resources is as follows: to preserve genetic diversity of tree species under changing environmental conditions, to provide favourable conditions for the evolution of tree species, to ensure sustainability of populations by special measures, to preserve these populations from negative environmental and anthropogenic factors. The impact of the complex of anthropogenic factors drastically changes the environment of natural habitats; therefore, the preservation of genetic diversity is especially significant to forest woody species in order to further adapt to the changing environmental conditions. The preservation of genetic potential of forest woody species is also necessary for selection in order to save the most productive population which adapts to local conditions best and includes maximum amount of genetic diversity (Kovalevič 2003).

This paper aims to investigate genetic diversity of the progenies of Quercus robur, Q. petraea and their hybrids that grow in the Trakas forest of Seirijai district of Alytus forest enterprise of Lithuania. Genetic studies were carried out by microsatellite (SSR) and RAPD methods.

Material and methods

Leaves have been collected from seedlings in Pajiesis plantations that are the progenies of Quercus genus in the Trakas forest of Seirijai district of Alytus forest enterprise. 164 samples have been investigated in total. The material of the experiment: tissue of leaves. The samples were divided into six groups by assignment of female tree and its open pollinated progeny (by prevalence in the family) to any of two oak species or their interspecific hybrid using mainly morphological traits of leaves:

- **Group No. 1** – ♀ Q. petraea (acorns were gathered from Q. petraea) – F₁ Q. petraea (the characteristics typical to the parental tree manifested in the progeny): 64 samples from 18 families;
- **Group No. 2** – ♀ Q. robur – F₁ Q. robur: 27 samples from 5 families;
- **Group No. 3** – ♀ Q. petraea – F₁ hybrid: 13 samples from 3 families;
- **Group No. 4** – ♀ Q. robur – F₁ hybrid: 10 samples from 2 families;
- **Group No. 5** – ♀ hybrid – F₁ Q. petraea: 11 samples from 3 families;
- **Group No. 6** – ♀ hybrid – F₁ hybrid: 39 samples from 8 families.

Microsatellite analysis (SSR) and RAPD analysis were used for the research on oak diversity according to their pedigree. The analysis consists of the following stages: DNA extraction, DNA amplification, electrophoretic fragmentation, analysis of obtained results.
The following components were used for DNA extraction: extraction buffer A (CTAB 2%, Tris-HCl 0.1M, NaCl 1.4M, EDTA 20mM), extraction buffer B (CTAB 5%, EDTA 350mM), precipitation buffer C (CTAB 1%, Tris-HCl 50mM, EDTA 10mM), solvent buffer D (NaCl 1M, Tris-HCl 10mM, EDTA 1mM), chloroform, isopropanol, ethanol 70%. DNA extraction consisted of the following stages: homogenisation and extraction, clean up of homogenates, DNA precipitation and clean up of DNA preparations.

Reactive mixture of the following composition was used for DNA amplification: 10×PGR buffer (100mM Tris-HCl, pH 9.2, 250mM KCl) – 2.5 ml; 25 mM MgCl2 – 2.5 mkl; water (PGR-reagent) – 16 mkl; mixture 5 mM nucleotide triphosphate - 1 mkl; 10 mM solution of each primer – 1 mkl, DNA sample (40 ng/ml) – 1 mkl, Taq/Pfu DNA-polymerase (5:1) (1 ed./ml) – 1 mkl.

Primers used for SSR analysis are given in Table 1, while the structure of RAPD primers is presented in Table 2.

Table 1. Characteristics of primers used for DNA microsatellite analysis of tree core of Quercus genus

<table>
<thead>
<tr>
<th>Locus</th>
<th>Primer nucleotide sequence (5’–3’)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ssrQpZAG15</td>
<td>CGATTTGATAATGACACTATGG CATCGACTCATTGTTAAGCAC</td>
</tr>
<tr>
<td>ssrQpZAG9</td>
<td>GCAATTACAGGCTAGGCTGG GTCTGGACCTAGCCCTCATG</td>
</tr>
<tr>
<td>ssrQpZAG46</td>
<td>CCCCTATTGAAGTCTAGGAGTCCCTAGGG</td>
</tr>
<tr>
<td>ssrQpZAG7</td>
<td>CGCACGACCACATGCCCAG</td>
</tr>
</tbody>
</table>

Table 2. Description of RAPD primers selected for the analysis of Quercus genus trees

<table>
<thead>
<tr>
<th>No.</th>
<th>Locus name</th>
<th>Nucleotide sequence 5’–3’</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>OP-R11</td>
<td>GTAGCCGTTCT</td>
</tr>
<tr>
<td>2</td>
<td>OP-R05</td>
<td>GACCTAGTGG</td>
</tr>
<tr>
<td>3</td>
<td>OP-R10</td>
<td>CCAATTCCCCA</td>
</tr>
<tr>
<td>4</td>
<td>OP-G06</td>
<td>GTGCCTAACC</td>
</tr>
</tbody>
</table>

Electrophoretic fragmentation in agar gel. The analysis of electrophoresis is carried out employing genetic analyser of SSR loci (SSR analysis). The following actions are made during the analysis: clean up of marked fragments, lyophilisation of marked fragments, preparation of samples, analysis and detection of electrophoresis. RAPD electrophoretic fragmentation analysis was made in electrophoresis unit Submarine (Sigma company). The electrophoresis was carried out at 4-8°C temperature for 2-2.5 hours under 4W current. Universal PS2001-2 energiser (Techuare company) was used during electrophoresis.

Analysis of obtained results. SSR analysis. Microsatellite markers are characterized by the manifestation of co-dominant type (except for “zero” alleles). Therefore, homozygous samples are displayed in densitograms in one main peak, while heterozygous samples are displayed in two (diploid tissues) and more (polyploid) electrophoretic options. The separation of alleles is made according to the name of the locus being investigated and its location size (in nucleotide pair) on the top of the column.

RAPD analysis. Markers are characterized by the manifestation of the dominant type and diallelic system: „1” – the attribution of the amplicon (dominant allele) and “0” – absence of amplicon (recessive allele), at one or another place of gel plate. Due to dominant markers of the given group, it is impossible to separate homozygous (according to dominant allele) and heterozygous genotypes. While characterizing the data, the spectrum of PCR fragments (phenotype) is described. The setting of zones was made according to the name of the marker selected by PCR and zone measurement (in nucleotide pair) above the column.

F<sub>ST</sub> Wright’s statistics (Wright 1965) and its analogue G<sub>ST</sub> Nei’s statistics (Nei 1972) are used for qualitative assessment of intra-specific genetic diversity.

Results and discussion

SSR analysis. Based on the results of SSR analysis, the assessment of the level of genetic differentiation of Quercus genus families was made employing Wright’s F-statistics (Table 3).

Positive F<sub>IS</sub> values in groups No. 1 (0.0070), No. 2 (0.0533) and No. 6 (0.0480) show insignificant (lower than 1%) lack of heterozygotes in the families of groups. Insignificant surplus of heterozygotes was ascertained only to groups No. 3 and No. 5 (-0.0070 and -0.0453 respectively). Almost a 45% lack of heterozygous genotypes was ascertained to the only group No. 4 (♀ Q. robur – F<sub>1</sub> hybrid). At the same time, when the values of individual inbreeding coefficients in regard to groups are low, individual inbreeding coefficients in regard to the total species is characterized in high values and vary from 0.1377 (Group No. 5) to 0.5158 (Group No. 4). Genetic differentiation coefficient (F<sub>ST</sub>) which measures the part of gene diversity between the groups ranges from 14.7% to 30.5%. The highest differentiation degree was ascertained for the hybrids of the second generation. The amount of migrants in the generation for samples being compared was low and did not exceed 1.5.
On the whole, the comparison of six groups as independent units (without division into families) has showed a significant growth of inbreeding coefficient $F_{IS}$ (up to 0.2595). Genetic differentiation coefficient ($F_{ST}$) decreases and amounts to 8.4%.

In these oak species using other molecular-marker techniques C.T. Kelleher et al. (2005) investigated genetic diversity of oak (*Quercus petraea* and *Q. robur*) populations by AFLP method. High $F_{ST}$ values estimated by AFLP have also showed markers and population differentiation ($F_{ST} = 0.271$). Species differentiation made only 13% of diversity variability if compared with differentiation of populations which amounted to 27%. This suggests that at a molecular level variation is partitioned more between populations than between species, with little evidence for species differentiation. During the investigation of the populations of *Quercus petraea* and *Q. robur* by AFLP method in Belgium (Coart et al. 2002), the analysis of the genetic structure of total populations has showed a high genetic differentiation between these two species ($F_{ST} = 0.0733$, $p < 0.0001$), while intra-specific differentiation was lower, but still significant for both *Q. petraea* ($F_{ST} = 0.0208$) and *Q. robur* ($F_{ST} = 0.0213$). Higher genetic diversity within populations of both species was obtained. C. Neophytou et al. (2010) used 14 nuclear microsatellite loci and were able to provide diverse information about differentiation patterns within and between *Q. petraea* and *Q. robur* using populations from Central Europe and the Balkans along an ecological gradient with increasing aridity towards south. $F_{ST}$ values between species are several times larger than among populations of the same species for these loci (*Q. petraea* - 0.049, *Q. robur* - 0.039 and interspecific - 0.101). Conversely, for another set of five loci they observed higher $F_{ST}$ values among populations of the same species, than between species in general.

The analysis of isozymes has been used for the investigation of *Quercus suber* plantations that grow in Spain, Portugal, Morocco and Italy (Jimenez et al. 1999). It should be noted that despite of low indicators of genetic variety (64% for polymorphic loci, the expected level of heterozigosity is 15.8%), they were similar to the average values of *Quercus* genus (Hamrick et al. 1992). Saplings which grow in the central part of the habitat being investigated and cover wide areas with the populations that grow in the edges. Plantations of low height must isolate the least reserves of genetic variability if compared with the central forests which have genetic mechanisms which maintain a relatively high level of diversity even when plantations are separated. Genetic differentiation between populations ($F_{ST}$) is 3.3% and shows significant gene flows or near expansion of postglacial habitat.

**RAPD analysis.** Genetic differentiation of *Quercus* genus families according to the results of RAPD analysis is given in Table 4.

<table>
<thead>
<tr>
<th>Group</th>
<th>$H_{T}$</th>
<th>$H_{S}$</th>
<th>$G_{ST}$</th>
<th>$N_{m}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. 1</td>
<td>0.3070</td>
<td>0.1695</td>
<td>0.4479</td>
<td>0.6163</td>
</tr>
<tr>
<td>No. 2</td>
<td>0.3170</td>
<td>0.2530</td>
<td>0.2020</td>
<td>1.9756</td>
</tr>
<tr>
<td>No. 3</td>
<td>0.3032</td>
<td>0.1734</td>
<td>0.4282</td>
<td>0.6678</td>
</tr>
<tr>
<td>No. 4</td>
<td>0.2817</td>
<td>0.2449</td>
<td>0.1305</td>
<td>3.3327</td>
</tr>
<tr>
<td>No. 5</td>
<td>0.2673</td>
<td>0.2223</td>
<td>0.1685</td>
<td>2.4676</td>
</tr>
<tr>
<td>No. 6</td>
<td>0.2732</td>
<td>0.1592</td>
<td>0.4173</td>
<td>0.6981</td>
</tr>
</tbody>
</table>

Note: $H_{T}$ – total genetic diversity of the group; $H_{S}$ – genetic diversity within the group; $G_{ST}$ – group subdivision coefficient; $N_{m}$ – gene flow.

The analysis has revealed that the total genetic diversity of the group ($H_{T}$) varied from 0.2673 (Group No. 5) to 0.3170 (Group No. 2) and in all the cases was higher than genetic diversity within the group ($H_{S}$). The total genetic diversity of the group in some groups (No.1, No. 3 and No. 6) was 1.5-2 times higher than the indicators of genetic diversity within the group: 0.3070:0.1695, 0.3032:0.1734; 0.2732:0.1592 respectively. It means that variability of the diversity among the groups takes 11-13%, while variability amounts to only 4-6% in groups No.2, No. 4 and No.5. Genetic differentiation coefficient ($G_{ST}$) that measures the part of gene diversity which is differentiated among the groups varies from 41.7% to 44.8% in groups No. 1, No. 3 and No. 4, i.e. such differentiation percent has been noticed among the given group families. Much higher genetic differentiation indicators which are typical to groups with *Q. petraea* can be explained by huge number of the parental trees that grow in the larger area, whereas the parental trees of *Quercus robur* are concentrated in the smaller area. It must be noted that a slightly lower total ($H_{T}$) and within the group ($H_{S}$) gene diversity has been noticed for hybrid progenies of the second generation (group No. 6) if compared with the progenies which have preserved parental characteristics. The values of the indicators of hybrids of the first generation (groups No. 3 and No.4) coincided with the values set for the groups No.1 and No. 2, respectively. Genetic diversity was similarly than in Irish and lower than in that found in other European studies (Kelleher et al. 2010).

The collections of population-based genetic indicators, which were compiled in the beginning of seventies of the last century, were used to assess genetic diversity. These collections do not only permit to properly describe genetic diversity.
structure of populations, but also permit to assess the level and condition of genetic diversity of populations and species without high financial and time loss (Padutov 2001). 

FS<sub>T</sub> Wright’s statistics (Wright, S. 1965) and its analogue GS<sub>T</sub> Nei’s statistics (Nei, 1972) that integrate (species as unity H<sub>e</sub>) and intra-population (H<sub>S</sub>, average due to local population) diversity between the individuals within population, are used for qualitative assessment of intra-specific genetic diversity. FS<sub>T</sub> statistics being a measure of genetic population part and equivalent of inbreeding individuals in the subcultures has significant biological meaning: it reflects the balance of gene fund differentiation and integration processes, and is auto-controlled parameter seeking stationery regime of population systems. Under these conditions, the negative reciprocal relation between genetically effectively abundant amount of local sub-populations (N<sub>e</sub>) and gene flows (immigration) into it (m) from locations of other species is ascertained: when effective abundance of sub-populations comprising the structure of population systems decreases, the intensity of gene immigration grows and vice versa. Such auto-control means maintenance of sustainable relations of homo- and heterozygous genotypes, i.e. the balance between inbreeding (interbreeding of congeneric species) and outbreeding (interbreeding of non-congeneric species) (Altuchova 2004). The flow of genes between the groups being investigated varied from 0.6163 to 3.3327. While interpreting N<sub>e</sub>m values, estimated by RAPD data (i.e. by indirect method), the following three categories are distinguished: N<sub>e</sub>m < 1 (the flow of genes is small in order to prevent from genetic differentiation resulted from genetic drift), N<sub>e</sub>m = 1–5 (the flow of genes can be sufficient or insufficient depending on specific conditions in order to prevent from drift effect), N<sub>e</sub>m > 5 (the flow of genes is sufficient in order to prevent from genetic differentiation resulted from gene drift). The obtained data on gene flow show that differentiating (the drift of genes) or integrating (the flow of genes) processes can dominate between the compared groups and hybrids.

Values which specify genetic differentiation for distinguished groups are given in Table 5.

### Table 5. Genetic differentiation of oak groups being investigated (RAPD analysis)

<table>
<thead>
<tr>
<th>Locus</th>
<th>H&lt;sub&gt;T&lt;/sub&gt;</th>
<th>H&lt;sub&gt;S&lt;/sub&gt;</th>
<th>G&lt;sub&gt;ST&lt;/sub&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>OP-R05&lt;sup&gt;545&lt;/sup&gt;</td>
<td>0.4931</td>
<td>0.4718</td>
<td>0.0433</td>
</tr>
<tr>
<td>OP-R05&lt;sup&gt;584&lt;/sup&gt;</td>
<td>0.2518</td>
<td>0.2406</td>
<td>0.0445</td>
</tr>
<tr>
<td>OP-R05&lt;sup&gt;717&lt;/sup&gt;</td>
<td>0.4115</td>
<td>0.3431</td>
<td>0.1663</td>
</tr>
<tr>
<td>OP-G06&lt;sup&gt;545&lt;/sup&gt;</td>
<td>0.2975</td>
<td>0.2829</td>
<td>0.0490</td>
</tr>
<tr>
<td>OP-G06&lt;sup&gt;001&lt;/sup&gt;</td>
<td>0.4202</td>
<td>0.3624</td>
<td>0.1375</td>
</tr>
<tr>
<td>OP-G06&lt;sup&gt;004&lt;/sup&gt;</td>
<td>0.2982</td>
<td>0.2821</td>
<td>0.0540</td>
</tr>
<tr>
<td>OP-G06&lt;sup&gt;017&lt;/sup&gt;</td>
<td>0.2405</td>
<td>0.2022</td>
<td>0.1592</td>
</tr>
<tr>
<td>OP-G06&lt;sup&gt;079&lt;/sup&gt;</td>
<td>0.3993</td>
<td>0.3559</td>
<td>0.1087</td>
</tr>
<tr>
<td>OP-R10&lt;sup&gt;008&lt;/sup&gt;</td>
<td>0.4683</td>
<td>0.4164</td>
<td>0.1108</td>
</tr>
<tr>
<td>OP-R10&lt;sup&gt;028&lt;/sup&gt;</td>
<td>0.1562</td>
<td>0.1517</td>
<td>0.0285</td>
</tr>
<tr>
<td>OP-R10&lt;sup&gt;022&lt;/sup&gt;</td>
<td>0.3575</td>
<td>0.3303</td>
<td>0.0760</td>
</tr>
<tr>
<td>OP-R10&lt;sup&gt;052&lt;/sup&gt;</td>
<td>0.1053</td>
<td>0.1050</td>
<td>0.0029</td>
</tr>
<tr>
<td>OP-R10&lt;sup&gt;111&lt;/sup&gt;</td>
<td>0.1886</td>
<td>0.1800</td>
<td>0.0456</td>
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<tr>
<td>OP-R10&lt;sup&gt;115&lt;/sup&gt;</td>
<td>0.4724</td>
<td>0.4524</td>
<td>0.0423</td>
</tr>
<tr>
<td>OP-R11&lt;sup&gt;008&lt;/sup&gt;</td>
<td>0.3834</td>
<td>0.3136</td>
<td>0.1821</td>
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<tr>
<td>OP-R11&lt;sup&gt;012&lt;/sup&gt;</td>
<td>0.3803</td>
<td>0.3010</td>
<td>0.2085</td>
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<td>OP-R11&lt;sup&gt;014&lt;/sup&gt;</td>
<td>0.3968</td>
<td>0.3561</td>
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<td>OP-R11&lt;sup&gt;076&lt;/sup&gt;</td>
<td>0.4008</td>
<td>0.3636</td>
<td>0.0927</td>
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<td>OP-R11&lt;sup&gt;085&lt;/sup&gt;</td>
<td>0.2490</td>
<td>0.2282</td>
<td>0.0834</td>
</tr>
<tr>
<td>On the average</td>
<td>0.3353</td>
<td>0.3021</td>
<td>0.0991</td>
</tr>
</tbody>
</table>

Note: H<sub>T</sub> – total genetic diversity of the group; H<sub>S</sub> – genetic diversity within the group; G<sub>ST</sub> – coefficient of group differentiation

The analysis has showed that the values of indicators of total genetic diversity (H<sub>T</sub>) according to RAPD loci were in all the cases higher than genetic diversity within the group (H<sub>S</sub>): 0.1053–0.4931 (the average value is 0.3353) and 0.1050–0.4718 (0.3021), respectively. Coefficient of group differentiation (G<sub>ST</sub>) in RAPD loci ranges from 0.0423 (OP-R10<sup>414</sup>) to 0.2085 (OP-R11<sup>612</sup>) and the average value is 0.0991. It shows about 10% variability between the formed groups, while over 90% of variability is present within the groups. The amount of migrants between the investigated groups was limited. Therefore, the estimated flow of genes N<sub>e</sub>m equalled 4.5, i.e. about 4-5 trees in each oak group being investigated have genotypes brought from adjacent groups. The obtained data shows a weak differentiation between the distinguished groups, i.e. between the progenies, which have maintained the characteristics of the parental trees Quercus petraea, Q. robur and hybrids and hereby this is a consequence of genetic exchange between the groups for both intra-specific and inter-specific.

A number of studies, which refer to the analysis of isoferments, focus and compare oak species, such as Quercus robur and Q. petraea (Zanetto et al. 1994, Bacilieri et al. 1995, Kleinschmit et al. 1995, Finkeldev et al. 2001, Yakovlev 2002). E.g. while investigating Q. robur and Q. petraea, A. Zanetto et al. (1994) have presented seven geographical pairs (plantations of different species belonged to one pair), which grow in the entire Europe (South West region of France, South Italy, Austria, Slovenia, Serbia, Romania and South Norway). Using a system of 11 isozymes, which is coding 13 loci, only insignificant differences of allele frequencies were ascertained and similar values of expected heterozygosity were distinguished (24.5% for Q. petraea, 25.2% for Q. robur). Genetic differentiation between the populations of each species separately was also small for both Q. robur (G<sub>ST</sub> = 2.4%) and Q. petraea (G<sub>ST</sub> = 3.2%) (Zanetto et al. 1994). While investigating the populations of Q. robur in the European part of Russia (Voronezh and Novgorod region, Republic of Mordovia and Bashkoria), a small differentiation coefficient (G<sub>ST</sub> = 0.098) was also ascertained; while gene flow N<sub>e</sub>m was 4.61 (Yakovlev 2002).
Conclusions

SSR analysis: positive FIS values in groups No. 1 (0.0070), No. 2 (0.0533) and No. 6 (0.0480) show insignificant (lower than 1%) lack of heterozygotes in the families of groups. Insignificant surplus of heterozygotes was ascertained only to groups No. 3 and No. 5 (-0.0070 and -0.0453 respectively). Almost a 45% lack of heterozygous genotypes was ascertained to the only group No. 4 (♀ Q. robur – F₁ hybrid). Genetic differentiation coefficient (FST) in families ranged from 13.8 to 51.6%. The comparison of six groups as independent units (without division into families) showed a significant increase of inbreeding coefficient (FIS) up to 0.2595, while genetic differentiation coefficient (FST) decreases and amounts to 8.4%.

RAPD analysis: total genetic diversity of the group (Hₑ) varied from 0.2673 (Group No. 5) to 0.3170 (Group No. 2) and in all the cases was higher than genetic diversity within the group (Hₛ). The total genetic diversity of the group in some groups (No.1, No. 3 and No. 6) was 1.5-2 times higher than the indicators of genetic diversity within the group: 0.3078:0.1695, 0.3032:0.1734; 0.2732:0.1592 respectively. It shows that variability of the diversity among the groups takes 11-13%, while variability amounts to only 4-6% in groups No.2, No. 4 and No.5. Genetic differentiation coefficient (Gₑ) that measures the part of gene diversity which is differentiated among the groups varies from 41.7% to 44.8% in groups No. 1, No. 3 and No. 6.

The highest differentiation degree was ascertained for the hybrids of the second generation.

The obtained data shows a weak differentiation between the distinguished groups, i.e. between the progenies, which have maintained the characteristics of the parental trees Q. petraea, Q. robur and hybrids this is a consequence of genetic exchange between the groups for both intra-specific and inter-specific.

Acknowledgement. The paper presents research findings, which have been obtained through long-term research programme "Sustainable forestry and global changes" implemented by Lithuanian Research Centre for Agriculture and Forestry.

References

A Case Study of the Wind-Wave Relationship in the Lithuanian Coast of the Baltic Sea

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Abstract

In the Lithuanian coastal observations registers missing data of visual wave observations occur because of the fog, ice, evaporation or other meteorological phenomenon. There is also inconsistency in instrumental measurements of wave heights in the Lithuanian coast due to technical issues. First step to fill the gaps in the wave height data is to find a correlation between wind speeds and wave heights. In this study correlation coefficients for Nida and Klaipėda coastal hydrometeorological stations data both taking and not taking into consideration wind blowing directions were calculated. Every data set used in this study was treated separately and it was revealed that applying nonlinear regression the most common model for wind-wave relationship analysis on Lithuanian coast is DR-Hill model, while applying multivariable regression it is Full Cubic model. Relationship between wind speeds and wave heights always can be improved by removing swell waves from correlation.

Keywords: regression analysis, wind speeds, wave heights, Lithuanian coast, Baltic Sea

Introduction

Wind waves originate during the process of wind blowing over the surface of water body. Wind transfers part of its energy into the water resulting into this natural phenomenon. Therefore, the relationship between wind speed and wave height may seem obvious. However, buoys, that are located in the oceans, are recording data not only of waves that are caused by the local wind, but also of waves that are born in storms in distant areas. Hence, there is no linear relationship between these parameters.

Manual wave forecasting diagram was developed by Groen and Dorrestein (1976). This diagram can be used to predict wave heights and periods when wind speed (m s\(^{-1}\)), its duration in hours and fetch (km) are known. But this easy to use diagram becomes difficult to apply at unsteady winds. Same can be said about any wave growth functions at the same conditions (Alomar et al., 2010). Limited fetch, unsteady winds and swell become reasons why predictions of significant wave heights as well as applications of wind wave generation and development functions are complicated not only in the ocean areas (Andreas and Wang, 2007; Hwang et al., 2011).

On the other hand, there is example of Lake Michigan, that is enclosed body of water and swell waves do not occur on such a large scale in these conditions, as they do in the open oceans. Thus, relationship via correlation between wind speed and wave height here can be found (Liu et al., 1984). It is already known, that wave fields in the Baltic Sea are similar to those on large lakes (Lepparanta and Myrberg, 2009).

For the statistical assessment of wave climate, extreme events and other studies it is necessary to use data from complete time series with constant intervals in time domain. Wave data are often incomplete due to various reasons and wind-wave correlations can be the method to fill the gaps in the wave height time series (Dreier et al., 2011). Instrumentally measured data in the Lithuanian coast of the Baltic Sea is available from 2011. Nevertheless, due to technical issues, collected data is irregular. Missing data of visual wave observations occur because of the fog, ice, evaporation or other meteorological phenomenon. Hence, finding a strong correlation can be the first step for developing a methodology to fill the gaps in wave height data.

The objective of this article is to assess the relationship between wind speeds and wave heights in the Lithuanian coast of the Baltic Sea by evaluating wind-wave correlations both taking and not taking into consideration wind blowing directions.

Materials and Methods

Observation data from Klaipėda and Nida coastal hydrometeorological stations was used for this study. Daily average wave heights and wind speeds were calculated using 1993-2008 coastal observations registers. Depending on a season visual observations of wave heights are performed and noted into this register two or three times during the daylight. In parallel wind speeds are noted in the same register, yet wind speeds are measured instrumentally.

Only observations of wind waves were used to calculate daily average wave heights. Swell waves were eliminated according to Manual for hydrometeorological stations and posts (Государственный..., 1984). In this manual wind-induced waves are described as sea in the direct effect of the same wind at the moment of observation. Wind blowing and wave propagation directions in deep water must coincide, or differ by no more than 45°. In shallow nearshore areas this difference can be greater, due to refraction (Государственный..., 1984). Observers of Environmental Protection Agency’s Department of Marine Research in Lithuania use this wind wave detection method to the present day. Furthermore, types of waves are always noted in the coastal observations register. In this register noted mixed type of waves (wind waves together with swell) were also eliminated from daily average wave heights calculations.

The assessment of wind-wave relationship is divided into two parts. In the first part linear and nonlinear regression analysis for wind waves at the same data sets is performed without taking into consideration wind blowing directions. In the second part multivariable regression analysis is performed (taking into consideration wind blowing
directions). Wind-wave correlation gained by multivariable regression is compared to results obtained by nonlinear regression for the same data sets. For each part of the assessment different sets of data was selected according to Kasiulis (2011).

Wind blowing directions are introduced by changing daily prevailing wind directions into selected coefficients. Coefficients were selected taking into account prevailing wind directions together with their fetches in the Lithuanian coast of the Baltic Sea (Fig. 1).

![Figure 1. Selected coefficients for wind blowing directions](image)

Study was carried out using Curve Expert software. All values of regression analysis results are presented with 95 % confidence interval. All equations to each data set are the best model fits based on standard error. Every data set is treated separately, because comparing the results gained by all types of regression is difficult. Use of correlation coefficients in nonlinear regression is questionable, while comparing via coefficient of determination is impossible, because best fitted models functions may have different number of independent variables. Only linear and nonlinear regression results are possible to compare via standard error.

In this study small correlation is from 0.2, medium correlation is from 0.5 and strong correlation from 0.7. This paper is continuation of research that was published in Kasiulis (2011).

### Results and Discussion

First attempt to evaluate relationship between wind speeds and wave heights in the Lithuanian coast by using simple linear regression was adopted in Kasiulis (2011). Annual correlations, using daily average wind speeds and wave heights from 1993-2008 Klaipėda and Nida coastal hydrometeorological stations data, were calculated (Table 1). After that, all 16 years daily average wind speed and wave height data of the same period from Nida coastal hydrometeorological station was put into one graph obtaining correlation coefficient of 0.72. All these results from Kasiulis (2011) were obtained by not taking into consideration wind blowing directions and including swell waves into correlation.

<table>
<thead>
<tr>
<th>Year</th>
<th>Klaipėda</th>
<th>Nida</th>
<th>Klaipėda</th>
<th>Nida</th>
<th>Klaipėda</th>
<th>Nida</th>
<th>Klaipėda</th>
<th>Nida</th>
<th>Klaipėda</th>
<th>Nida</th>
<th>Klaipėda</th>
<th>Nida</th>
</tr>
</thead>
<tbody>
<tr>
<td>1993</td>
<td>0.85</td>
<td>0.61</td>
<td>0.68</td>
<td>0.53</td>
<td>0.55</td>
<td>0.53</td>
<td>0.81</td>
<td>0.76</td>
<td>0.81</td>
<td>0.76</td>
<td>0.82</td>
<td>0.82</td>
</tr>
<tr>
<td>1994</td>
<td>0.74</td>
<td>0.74</td>
<td>0.74</td>
<td>0.53</td>
<td>0.73</td>
<td>0.76</td>
<td>0.75</td>
<td>0.75</td>
<td>0.72</td>
<td>0.73</td>
<td>0.66</td>
<td>0.64</td>
</tr>
<tr>
<td>1995</td>
<td>0.46</td>
<td>0.38</td>
<td>0.82</td>
<td>0.71</td>
<td>0.65</td>
<td>0.65</td>
<td>0.58</td>
<td>0.70</td>
<td>0.64</td>
<td>0.65</td>
<td>0.62</td>
<td>0.64</td>
</tr>
<tr>
<td>1996</td>
<td>0.80</td>
<td>0.66</td>
<td>0.64</td>
<td>0.77</td>
<td>0.62</td>
<td>0.63</td>
<td>0.72</td>
<td>0.73</td>
<td>0.72</td>
<td>0.73</td>
<td>0.72</td>
<td>0.72</td>
</tr>
<tr>
<td>1997</td>
<td>0.62</td>
<td>0.66</td>
<td>0.66</td>
<td>0.74</td>
<td>0.69</td>
<td>0.70</td>
<td>0.74</td>
<td>0.72</td>
<td>0.72</td>
<td>0.74</td>
<td>0.66</td>
<td>0.65</td>
</tr>
<tr>
<td>1998</td>
<td>0.64</td>
<td>0.71</td>
<td>0.64</td>
<td>0.70</td>
<td>0.49</td>
<td>0.62</td>
<td>0.64</td>
<td>0.70</td>
<td>0.64</td>
<td>0.64</td>
<td>0.72</td>
<td>0.72</td>
</tr>
<tr>
<td>1999</td>
<td>0.78</td>
<td>0.64</td>
<td>0.72</td>
<td>0.72</td>
<td>0.77</td>
<td>0.76</td>
<td>0.64</td>
<td>0.70</td>
<td>0.72</td>
<td>0.71</td>
<td>0.72</td>
<td>0.71</td>
</tr>
<tr>
<td>2000</td>
<td>0.73</td>
<td>0.70</td>
<td>0.74</td>
<td>0.72</td>
<td>0.76</td>
<td>0.73</td>
<td>0.74</td>
<td>0.70</td>
<td>0.72</td>
<td>0.71</td>
<td>0.72</td>
<td>0.71</td>
</tr>
</tbody>
</table>

According to Table 1 there are not only 12 cases of medium, but even 3 cases (Klaipėda and Nida 1996; Klaipėda 2006) of small correlation between wind speeds and wave heights. Thus, from this set of data it is clear that it is misleading to state that there is linear relationship between wind speeds and wave heights in the Lithuanian coast. First step of this study is to repeat simple linear regression analyses to the same data sets from which swell waves are eliminated. All data sets with small correlation are selected for this part of study. Results are presented in Table 2.

<table>
<thead>
<tr>
<th>Coastal hydrometeorological station</th>
<th>Year</th>
<th>Linear equation $y = a+bx$</th>
<th>Annual correlation coefficient</th>
<th>Standard error</th>
<th>Coefficient of determination</th>
</tr>
</thead>
<tbody>
<tr>
<td>Klaipėda</td>
<td>1996</td>
<td>-0.10 0.14</td>
<td>0.81</td>
<td>0.23</td>
<td>0.66</td>
</tr>
<tr>
<td>Nida</td>
<td>1996</td>
<td>0.05 0.11</td>
<td>0.78</td>
<td>0.20</td>
<td>0.62</td>
</tr>
<tr>
<td>Klaipėda</td>
<td>2006</td>
<td>-0.16 0.18</td>
<td>0.82</td>
<td>0.26</td>
<td>0.67</td>
</tr>
</tbody>
</table>
Elimination of swell waves changes correlation between wind speeds and wave heights from small to strong. Still, this linear equation cannot be used to fill the gaps in wave height data, because not only the standard errors indicate that dispersion around the regression line is relatively large, but also coefficients of determination indicate that regression line does not fit the data well. This can be improved by applying nonlinear equations (use of higher than 5th degree polynomial regressions is avoided). Example of linear and nonlinear regression model fit is shown in Fig. 2.

![Linear and nonlinear regression model fit for Klaipėda coastal hydrometeorological observation data (year 1996)](image)

By applying 5th degree polynomial regression (equation $y = a + bx + cx^2 + dx^3 + ex^4 + fx^5$, parameters $a = 0.13, b = 0.12, c = -0.03, d = 0.003, e = 0.0004, f = -0.00003$) to the Klaipėda coastal hydrometeorological data (the year 1996) these values were obtained: correlation coefficient of 0.91, standard error of 0.20 and coefficient of determination of 0.83. In parallel gained values using nonlinear regression that were obtained for other data sets are presented in Table 3. Results of standard errors of nonlinear regression analysis indicate that nonlinear regression line gives more accurate prediction of wave heights (Fig. 2). Basically, this line is reliable for filling the gaps in wave height data on Klaipėda coast, however, its use is questionable on Nida coast.

Next part of this study is assessment of the relationship between wave heights and wind speeds in the Lithuanian coast by taking into consideration wind blowing directions. For this part data sets with medium - 0.62 (Klaipėda 1998 and Nida 2006) and strong - 0.76 (Klaipėda 2008 and Nida 2002) correlation were selected (Table 1). Firstly, in order to determine if taking into consideration wind blowing directions can improve reliability of wave height prediction, nonlinear regression analysis for these four data sets was performed. The obtained results are presented in Table 3.

### Table 3. Results of nonlinear regression analysis

<table>
<thead>
<tr>
<th>Name</th>
<th>Equation</th>
<th>Parameters</th>
<th>Annual correlation coefficient</th>
<th>Standard error</th>
<th>Coefficient of determination</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nida 1996</td>
<td>Gaussian</td>
<td>$y = ae^{-\frac{(x-b)^2}{2c^2}}$</td>
<td>$a = 2.2, b = 19.1, c = 8.4$</td>
<td>0.79</td>
<td>0.20</td>
</tr>
<tr>
<td>Klaipėda 2006</td>
<td>DR-Hill</td>
<td>$y = \frac{\alpha \cdot x^\theta}{\kappa^{\eta} + x^{\theta}}$</td>
<td>$\alpha = 0.28, \theta = 2.2, \eta = 4.5, \kappa = 7.7$</td>
<td>0.87</td>
<td>0.23</td>
</tr>
<tr>
<td>Klaipėda 1998</td>
<td>Polynomial (5th degree)</td>
<td>$y = a + bx + cx^2 + dx^3 + ex^4 + fx^5$</td>
<td>$a = -0.20, b = 0.71, c = -0.34, d = 0.07, e = -0.005, f = 0.0001$</td>
<td>0.92</td>
<td>0.22</td>
</tr>
<tr>
<td>Nida 2006</td>
<td>Polynomial (3rd degree)</td>
<td>$y = a + bx + cx^2 + dx^3$</td>
<td>$a = 0.31, b = 0.10, c = 0.04, d = -0.002$</td>
<td>0.91</td>
<td>0.27</td>
</tr>
<tr>
<td>Klaipėda 2008</td>
<td>DR-Hill</td>
<td>$y = \frac{\alpha \cdot x^\theta}{\kappa^{\eta} + x^{\theta}}$</td>
<td>$\alpha = 0.28, \theta = 2.2, \eta = 4.5, \kappa = 7.7$</td>
<td>0.92</td>
<td>0.22</td>
</tr>
</tbody>
</table>
Next step is to perform multivariable (3D) regression analysis by adding into consideration wind blowing directions. Applying multivariable regression change equation and values of standard error, so comparing it is not expedient. Therefore nonlinear and multivariable regression analysis results are non-comparable. Here presented results of multivariable (3D) regression are best fits for each data set via standard error.

Multivariable Rational regression (equation $y = (a + bx_1 + cx_2) / (1 + dx_1 + ex_2)$, parameters $a = -1.9, b = 20.1, c = 1.9, d = 1.3, e = 0.83$) was applied for 1998 Klaipėda data set. Obtained correlation coefficient and coefficient of determination are: 0.92 and 0.84. For the rest three data sets Full Cubic regression was applied. Full Cubic equation with parameters for each data set is presented in Table 4.

<table>
<thead>
<tr>
<th>Data set</th>
<th>$a$</th>
<th>$b$</th>
<th>$c$</th>
<th>$d$</th>
<th>$e$</th>
<th>$f$</th>
<th>$g$</th>
<th>$h$</th>
<th>$i$</th>
<th>$j$</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006 Nida</td>
<td>-0.18</td>
<td>10.2</td>
<td>0.22</td>
<td>-3.2</td>
<td>0.80</td>
<td>0.44</td>
<td>0.38</td>
<td>-2.6</td>
<td>1.1</td>
<td>-0.83</td>
</tr>
<tr>
<td>2008 Klaipėda</td>
<td>-1.1</td>
<td>16.7</td>
<td>0.26</td>
<td>-11.2</td>
<td>-0.07</td>
<td>2.6</td>
<td>0.71</td>
<td>-4.5</td>
<td>2.5</td>
<td>-0.17</td>
</tr>
<tr>
<td>2002 Nida</td>
<td>-1.1</td>
<td>14.3</td>
<td>-2.2</td>
<td>-7.7</td>
<td>1.0</td>
<td>1.6</td>
<td>0.64</td>
<td>2.4</td>
<td>0.26</td>
<td>-1.9</td>
</tr>
</tbody>
</table>

Using multivariable regression gained correlation coefficients and coefficients of determination are: for Nida 2006 - 0.90 and 0.81; for Klaipėda 2008 - 0.92 and 0.85; for Nida 2002 - 0.86 and 0.75. The example of multivariable regression model fit results is presented in Fig. 3.

![Figure 3. Multivariable regression model fit for Nida coastal hydrometeorological observation data (year 2002)](image-url)

**Conclusions**

A small linear wind-wave relationship can be transformed into strong by eliminating swell waves from correlation. The best improvement was gained using Nida 1996 data set (from 0.38 to 0.78).

Applying nonlinear regression revealed that the most common model for wind-wave relationship analysis on the Lithuanian coast is DR-Hill model (3 cases of best fit). Still, the lowest standard error was gained applying 5th degree polynomial regression model (Klaipėda 1996; 0.16).

Applying multivariable regression for wind-wave relationship analysis by taking into account wind blowing directions revealed that the most common model is Full Cubic model (3 cases of best fit). The best combination of correlation coefficient and coefficient of determination was gained using Klaipėda 2008 data set (0.92 and 0.85).

**Acknowledgements.** The author would like to acknowledge EPA Department of Marine Research in Lithuania for providing Klaipėda coastal hydrometeorological station data.

**References**


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Evaluation Aspects of Return on Assets and Equity in State Forestry in Lithuania

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Abstract

This paper addresses the evaluation aspects of return on assets as well as equity considering state forestry in Lithuania. According developed methodology of forest value determination the state commercial forests (III and IV groups) is evaluated. M. Faustmann approach is applied to determine the value of forest land and forest stands using alternate interest ratios (1; 2; 3; 6.25; 6.5 %). Evaluation aspects of the indicators of Return on Assets (ROA) also Return on Equity (ROE) are analysed in state forestry.

4.6 %, while margin to evaluate long-term projects was from 0.6 to 2.6 %.

Calculating state forest value from 8872.1 to 1536.6 mill. EUR respectively to interest rates set in this research. Pine, spruce and birch stands have the highest value share out of total forest value. However, the highest average value per ha retain oak and aspen stands. According to analysis of ROA and ROE indicators, the recommendations in respect to return on assets and equity determination as well as evaluation in state forestry are provided.

Key words: state forest, value, return on assets, return on equity.

Introduction

Lithuanian state forests are managed under the right of confidence by state forest enterprises (SFE). SFE are self-financing integrated management entities (forest protection, regeneration, felling, timber extraction and sales) working under principles of sustainable development. SFE manage ~1 mill. ha of forest land, annual allowable cut is ~3.6 mill. m³. The intensive economical activity is performed only in commercial forests (III and IV groups); the share of these forests is around 86 % out of total state forest land. 90 % of SFE income is generated from revenues of roundwood.

SFE are imposed usual taxes of the Republic of Lithuania, additionally, SFE are imposed compulsory deductions of 5 % from revenues of roundwood and standing timber sales for the common financial needs of forestry as well as compulsory deductions of 10 % from revenues of roundwood and standing timber sales for the state budget. According to Forest Act (10th April 2001), the value of forest land and forest is not included in balance sheet of SFE.

In 2009, by initiative of the Government of the Republic of Lithuania, the reform concerning State owned enterprises efficiency started. The main idea of this reform was to increase the return on equity (ROE) (Deputy if Prime Minister... 2009). The ROE was the main indicator to indicate the efficiency in state owned enterprises. The emphasis has to be put on efficiency comparison between state owned enterprises, because there is no performed analysis for the specific of the economic sectors including forestry. In the process of State forest sector efficiency evaluation, forest value was set as SFE asset. Therefore, as there was no unanimously accepted methodologies for forest value determination, the forest value was set as a directive (0.84-0.96 bill. EUR). Obviously, the forest value was determined by Missbars (1993; 2002; 2006; 2011) or common forest value is available in data basis of Forest Cadastre, notwithstanding, the factual forest value determination has not been ever made using interest rate in stands level.

Purpose of investigation – to determine the return on assets and equity in state forestry in Lithuania.

Tasks:
1. To suggest the methodology of forest value evaluation according to wood supply function;
2. To evaluate state forests respecting wood supply function that guarantees revenues to forest managers;
3. To determine the return on assets and equity in state forestry;
4. To provide the recommendations concerning return on assets and equity determination and evaluation in state forestry.

Object – the determination of return on assets and equity in state forestry.

Research methods

M. Faustmann (1849) formula is used to calculate state commercial forest value in this research. The following advisable and widely used (Price, 1993; Duer, 1993) traditional interest rates are applied in forest value determination: 1%, 2% and 3%; also the interest rate of 6.25 % used by Swedish state forest enterprise Sveaskog (Annual report, 2009) is applied. Additionally, the interest rate of 6.5 % is used. This ratio was determined according to 9 year period reports of the Central Bank of the Republic of Lithuania (2010); therefore, Vilnius Interbank Offered Rate (VILIBOR) was 4.6 %, while margin to evaluate long-term projects was from 0.6 to 2.6 %.

To find out the SFE revenues from roundwood in cutting age, average roundwood prices by assortments that are publicly announced by Directorate General of State Forest of the period from 2008 to 2010 are used. To identify the costs of harvesting, the factual data of SFE is used and the average of the period from 2008 to 2010 was calculated.

According to the Order No. D1-133 of the Minister of the Environment “Concerning validation of order of compulsory standards determination regarding forest establishment, protection and arrangement” that came in to force on 25th March 2004, the following costs were included in determination of annual SFE expenditures: sanitary and fire protection, forest arrangement; costs of personnel of forest management and 60% of costs of administration of forest districts; similarly, the average of these costs from 2008 to 2010 was calculated.
Value of state commercial forests is determined using Standwise Forest Inventory database on the stand level. Stands were grouped regarding dominant tree species using GIS ArcMap software by joining forest standwise database of 1st and 2nd forest storries.

The following 8 main dominant tree species are distinguished in forest stands to determine forest value: pine, spruce, oak, ash, birch, black alder, aspen, grey alder, additionally, other hardwood tree species (OHTS) and other deciduous tree species (ODTS) stands were distinguished as well. OHTS included the stands of maple, hornbeam, elm and other hardwood dominant tree species, ODTS included the stands of lime, poplar, sallow, willow and other dominant deciduous tree species. The stands of larch, grey pine, Austrian pine, mountain pine are included in pine stands; and the stands of fir and other coniferous were included in spruce stands in this research.

Using forest yield level model (Tebera, 1987) the prognosis of mature forest stock is made in stand level. Forest yield level, and the stock of mature stands is prognosticated by dominant tree species, while the structure of assortments is calculated to each tree species according to coefficients of tree species structure of the stands. Visual Basic programming language was applied to determine both the structure and the value of the stands. Forest yield tables (Petrauskas et al., 2010) are used to determine volume of timber assortments. To determine the value of mature and overmature stands the factual stock of stand is used applying Standwise Forest Inventory database. Because of inaccuracy of stock prognosis model for the stands that were less than 30 years age, the average of present mature and overmature stands is used as the stock of these stands in mature age.

Financial indices characterizing SFE performance are analysed using the following documents:
- “Basic economic-financial indicators in State forest enterprises (F-01–MŪ)“;
- “Performance of compulsory standards of forest establishment, protection and arrangement works (MŪ-15)“;

Finally, the return on assets and equity in SFE is calculated.

Results of the research

In SFE, forest value is not included in accounting, consequently, forest value as biological asset has to be determined. According Deltuvas et al. (2011) performed comparison between EU countries accounting systems in State forest entities the following practices respecting forest value set in accounting are used:
- forest value is not included in accounting (Poland, Latvia);
- forest land value is included in accounting (some States in Germany, for instance, Lower Saxony)
- both, forest land and stands are included in accounting (Swedish State Stock Company Sveaskog, State Forest Enterprise RMK in Estonia)

Respecting available methodologies regulating forest value determination, the current costs of future income and expenditures regarding forestry is not taken into consideration. Thus, in scientific literature, broadly accepted M.Faustamm forest value determination approach is used to calculate not only current costs value of forest stand but also to determine forest stand value for unlimited rotation periods in the future. Calculated value of State commercial forest using alternate interest ratios by dominant tree species in Lithuania is provided in table No. 1.

### Table 1. Value of State importance forest

<table>
<thead>
<tr>
<th>Dominant tree species</th>
<th>Stands value, mill. EUR</th>
<th>Mean value, EUR/ha</th>
<th>Area, ha</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.01</td>
<td>0.02</td>
<td>0.03</td>
</tr>
<tr>
<td>Pine</td>
<td>3084.0</td>
<td>1732.2</td>
<td>1255.6</td>
</tr>
<tr>
<td>Spruce</td>
<td>3233.7</td>
<td>1671.3</td>
<td>1175.7</td>
</tr>
<tr>
<td>Oak</td>
<td>208.7</td>
<td>126.4</td>
<td>94.4</td>
</tr>
<tr>
<td>Ash</td>
<td>195.0</td>
<td>156.1</td>
<td>36.1</td>
</tr>
<tr>
<td>Birch</td>
<td>1664.2</td>
<td>978.5</td>
<td>761.7</td>
</tr>
<tr>
<td>Aspen</td>
<td>399.5</td>
<td>253.6</td>
<td>184.6</td>
</tr>
<tr>
<td>Black alder</td>
<td>129.1</td>
<td>71.6</td>
<td>51.5</td>
</tr>
<tr>
<td>Grey alder</td>
<td>35.2</td>
<td>19.2</td>
<td>13.9</td>
</tr>
<tr>
<td>OHTS*</td>
<td>7.1</td>
<td>3.5</td>
<td>2.2</td>
</tr>
<tr>
<td>ODTS**</td>
<td>15.5</td>
<td>9.8</td>
<td>8.1</td>
</tr>
</tbody>
</table>

*Other hardwood tree species
**Other deciduous tree species

The pine, spruce and birch stands took the greatest value share out of total forest value irrespective of interest rates used in determination. The highest average value per ha retained oak and aspen stands. The high value of aspen and ODTS stands is connected to short rotation, because in the process of discounting the priority is set for the earlier income. The low value of ash stands is related to the poor sanitary conditions (Fig. 1).
The emphasis has to be put on the amount of interest rates that has crucial impact to total forest value. It was estimated that state commercial forest value was from 1536.6 to 8872.1 mill. EUR in Lithuania respectively applied interest rates. Consequently, the discount rate had crucial impact not only to the amount of forest value but also to the interpretation of ROA and ROE as these indices are strongly related to SFE asset and economic indicators of the entities. The common data of SFE financial statement was obtained in collaboration with Directorate General of State Forests (Table 2).

<table>
<thead>
<tr>
<th>Indices</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>State forest of commercial purpose, thousand. ha</td>
<td>822.8</td>
<td>826.8</td>
<td>854.4</td>
<td>861.2</td>
<td>863.8</td>
<td>867.3</td>
<td>871.2</td>
<td>872.6</td>
<td>895.2</td>
</tr>
<tr>
<td>Annual allowable cut, mill. m³</td>
<td>3.8</td>
<td>3.7</td>
<td>3.6</td>
<td>3.6</td>
<td>3.5</td>
<td>3.5</td>
<td>3.5</td>
<td>3.7</td>
<td>3.5</td>
</tr>
<tr>
<td>Value of fixed assets, mill. EUR</td>
<td>45.8</td>
<td>47.8</td>
<td>51.1</td>
<td>58.1</td>
<td>65.5</td>
<td>74.3</td>
<td>82.5</td>
<td>75.9</td>
<td>80.3</td>
</tr>
<tr>
<td>Value of current assets, mill. EUR</td>
<td>37.6</td>
<td>33.1</td>
<td>33.5</td>
<td>36.3</td>
<td>65.5</td>
<td>55.5</td>
<td>52.2</td>
<td>54.9</td>
<td>67.1</td>
</tr>
<tr>
<td>Total revenues, mill. EUR</td>
<td>87.6</td>
<td>88.5</td>
<td>93.9</td>
<td>108.7</td>
<td>113.6</td>
<td>149.3</td>
<td>138.3</td>
<td>102.1</td>
<td>120.2</td>
</tr>
<tr>
<td>Total costs, mill. EUR</td>
<td>80.3</td>
<td>82.1</td>
<td>91.3</td>
<td>99.7</td>
<td>118.0</td>
<td>128.3</td>
<td>95.7</td>
<td>104.1</td>
<td></td>
</tr>
<tr>
<td>Costs of administration, mill. EUR</td>
<td>24.9</td>
<td>25.5</td>
<td>27.6</td>
<td>30.4</td>
<td>32.4</td>
<td>36.8</td>
<td>37.5</td>
<td>26.6</td>
<td>28.8</td>
</tr>
<tr>
<td>Cost of forest sanitary protection, mill. EUR</td>
<td>0.4</td>
<td>0.6</td>
<td>0.5</td>
<td>0.9</td>
<td>1.0</td>
<td>1.4</td>
<td>1.4</td>
<td>1.6</td>
<td>1.2</td>
</tr>
<tr>
<td>Costs of forest fire protection, mill. EUR</td>
<td>0.9</td>
<td>0.8</td>
<td>0.9</td>
<td>1.0</td>
<td>1.4</td>
<td>1.4</td>
<td>1.6</td>
<td>1.1</td>
<td>1.2</td>
</tr>
<tr>
<td>Costs of forest arrangement, mill. EUR</td>
<td>4.7</td>
<td>5.5</td>
<td>6.3</td>
<td>7.7</td>
<td>7.4</td>
<td>12.3</td>
<td>12.5</td>
<td>7.8</td>
<td>9.5</td>
</tr>
<tr>
<td>Net profit, mill. EUR</td>
<td>4.7</td>
<td>3.9</td>
<td>3.4</td>
<td>8.5</td>
<td>6.0</td>
<td>20.9</td>
<td>3.5</td>
<td>0.8</td>
<td>1.2</td>
</tr>
<tr>
<td>Taxes, mill. EUR</td>
<td>22.9</td>
<td>21.9</td>
<td>23.9</td>
<td>27.6</td>
<td>27.8</td>
<td>386</td>
<td>33.3</td>
<td>31.4</td>
<td>36.7</td>
</tr>
</tbody>
</table>

The results revealed (table 2) decreasing trend (except 2007) respecting net profit in SFE, hence, this decreasing trend could be connected to increased taxes. Nevertheless, the value of fixed assets as well as value of current assets was increasing in SFE. As the annual allowable cut was stable in SFEs the total income was growing. SFE reports (F-01–MŪ and MŪ-15) showed steady reduction in costs for forest sanitary protection, maintenance of irrigation system, preparation of scientific research objects in forest, protection for game management in SFE.

Determined ROA and ROE in SFE using interest rate 6.5 % is given in Table 3.

<table>
<thead>
<tr>
<th>ROA</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excluding forest value</td>
<td>8.4</td>
</tr>
<tr>
<td>Including forest value</td>
<td>0.7</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ROE</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excluding forest value</td>
<td>16.1</td>
</tr>
<tr>
<td>Including forest value</td>
<td>1.3</td>
</tr>
</tbody>
</table>

As the accounting of social purpose costs that did not generate income in SFEs was not regulated, these costs were included in the process of ROA and ROE determination. Whereas, the social purpose costs were excluded in EU state forest sector accounting, additionally, these costs (fully or partly) were reimbursed by state budget. Thus, in Lithuania, ROA and ROE had to be reflected by taxes on economic activity and profit in state forest sector.

During the process of ROA and ROE determination in Lithuania the following recommendations were formulated:
- the current annual felling value as biologic asset generating profit in SFEs in standing forest prices have to be included in ROA and ROE determination;
- the net profit after profit tax could be increased not only by including compulsory deductions from revenues of roundwood and standing timber sales for the common financial demands of forestry and state budget, but also by taxes on asset in SFE.
To follow these recommendations ROA could be from 8 to 10 %, while ROE even higher depending on the amount of equity in liability of SFEs balance-sheet.

In forestry, economic outputs depend not only on dynamic markets of round wood, but also on demand of forest services, consequently, ROA and ROE determination and improvement have to be made considering changes in State forest sector (mainly to the dynamics of roundwood market and forest processing costs). Moreover, social purpose costs that do not generate income in SFE are recommended to determine according order No. 1B-309 (came into force 03 08 2011) together with order No. 1B-408 (came into force 03 08 2011) signed by director of Directorate of State Forests. Thus, social purpose costs have to be out of ROA and ROE determination.

International standard IAS 41 could be the alternative to ROA and ROE determination. According IAS 41 the value of forest could be estimated forecasting cash flow considering forest stand structure of tree species, volume and age. Three year average of interest rate could be used to discount the cash flow.

The ROA and ROE of State forest sector would not have been compared to other economic sectors; hence, these economic criteria could be compared to internal profit ratio of SFE. If forest value was included in SFEs asset, ROA and ROE would have been around 1.5-1.7 %. Therefore, this amount is very close to widely recognized (Price, 1989) in Europe considering forest productivity, structure of tree species, felling ratio is from 1 to 3 %.

Conclusions and recommendations

It is advisable to use M. Faustmann formula in forest value determination according wood supply function. Total forest value could be determined additionally including not only non-forest goods, but also ecological and social functions values.

The value of Lithuania State commercial forest according wood supply function both applying 3 year average of roundwood prices and costs to forestry, timber processing and management varies from 1536.6 to 8872.1 mill. EUR respectively to applied interest rates from 1.0 to 0.65%.

According to EU practices the interest rates in forest value determination is the object of policy decision makers. In Lithuania, the interest rate could be determined by Directorate general of State Forests adopted board representing all stakeholders.

According 9 year average (4.6 %) of Vilnius Interbank Offered Rate (VILIBOR) and improved margin (0.6–2.6 %) it is recommended to apply 6.5% interest rate in state forest value determination.

The following two options of value inclusion to State Forest Enterprises asset upon which ROA and ROE are determined are offered: first, the value determined according methodology of this research or, second, the value of annual factual cut in standing forest prices.

The social purpose costs that did not generate income in SFE have to be excluded from the costs generating income, therefore social purpose costs have to be included in net profit. Considering forestry specifics, the ROA and ROE of State forest sector should not be compared to other state owned entities.

References


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DNA Differentiation Among four Lithuanian Scots Pine Populations

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Aleksandras Stulginskis University, Lithuania

Abstract

Most of the former studies on genetic differences between Scots pine populations in Lithuania were based phenotype. The interest is to investigate population differentiation within Lithuania based on neutral variable DNA markers such as microsatellites. Objective of the study was to assess genetic differences between 4 Lithuanian populations representing 4 different adaptive environments based on nuclear (nSSR), chloroplast (cpSSR) microsatellites and mitochondrial DNA NAD7.1 locus. The main aim was to pre-screen the efficiency of a larger number of loci to reveal population differences within Lithuania to be further used on a large material. 7 nSSR loci, 8 cpSSR loci and 1 mtDNA locus were studied in each of the following populations: Labanoras (eastern Lithuania), Juodkrantė (western), Višakio Rūda (central) and Mažeikiai (northern). The mtDNA results revealed no marked differences in the frequency of the northern type of mtDNA Nad7.1 295 bp allele with the tendency of slightly higher frequency in the eastern populations. Based on the cpSSR loci, the population differentiation was significant and the among-population variance component was markedly greater than that for the nSSRs. The multilocus clustering based on the cpSSR genetic distance revealed greater similarity between the western Lithuanian populations and genetic separation of central Lithuanian population. Whereas according to the multilocus nSSR clustering, the sea-side spitz of Neringa was distinguishing from the rest and the two northern-most populations from Labanoras and Mažeikiai shared a single cluster. In conclusion, our study showed a significant population differentiation especially at the cpSSR loci within Lithuania and provided the background for a more detail investigation based on the loci studied. Merging of present-day regions of provenance are discussed.

Introduction

Understanding the adaptation to local environmental conditions through population differentiation is important for seed zoning, gene conservation and breeding (Nei 1973, Savolainen et al. 2007). The former studies of genetic differences between Scots pine populations in Lithuania were based on the phenotype (Danusevicius 2000; 2008). Our interest is to investigate population differentiation within Lithuania based on neutral variable DNA markers such as microsatellites. Before starting the large-scale study, we attempt to pre-select a set of the most efficient loci on a smaller scale set representing geographically distant populations within the frames of Lithuania.

Microsatellites or simple sequence repeats (SSR) are widely used molecular markers in population differentiation studies of pines (e.g. Neatle and Sederoff 1989; Jaramillo-Correa et al. 2003). Recently a number of studies revealed a significant within-country population differentiation based on variable sets of SSR markers (Soranzo et al. 2000, Robledo-Arnuncio et al. 2005, Pyhäjärvi at al 2008). These markers may be region-specific and prescreening with the Baltic Scots pine material is needed. Naydenov et al. (2007) based on the mitochondrial DNA markers, revealed two distinct haplotypes representing different glacial refugia for Scots pine: (a) multiple refugia in southern Europe referred to as universal haplotype represented by the 300 bp allele; (b) northern refugium, much smaller in geographical area, mainly found in the Baltic, Karelian (north-western part of Russia) and Finnish populations; called the northern haplotype represented by the 295 bp allele (confirmed by Chernova et al. 1991; Chedadi et al. 2006). Our interest is to investigate the mtDNA haplotype variation within Lithuania to assess possible evolutionary differences of Scots pine within the country.

The objective of the study was to assess genetic differences between 4 Lithuanian populations representing different adaptive environments based on nuclear (nSSR), chloroplast (cpSSR) microsatellites and mitochondrial DNA NAD7.1 locus. The main aim was to pre-screen the efficiency of a larger number of loci to reveal population differences within Lithuania to be further used on a large material.

Material and Methods

Four populations representing different adaptive environments were selected for the study: Juodkrantė (sea-side lowland), Mažeikiai western highland, Labanoras (eastern highland) and Višakio Rūda central lowland (southern part). Needles of 10 individuals were sampled in each population. The DNA was extracted from 100 mg of fresh needles by the CTAB protocol (Doyle & Doyle, 1990). For the mtDNA Nad7-1 locus the following primers were used: the forward primer sequence is 5′-6FAM-ATACCGTCTGGGAAAAACCGCGG-3′ (6FAM); the reverse primer sequence was 5′-GGCCTCTCATTTCCATGACCCG-3′ (no dye). The PCR was carried as described in Buchovska et al 2013. For the cpDNA study 7 loci and the corresponding dye labeled primers were used (described by Vendramin et al., 1996). PCR conditions are given in Vendramin et al. (1996). For the nDNA study, 8 nDNA loci were used (Soranzo et al 1998). The PCR was carried out as described by Soranzo et al. (1998). For all the DNA loci studied the fluorescence-labeled PCR products were separated by capillary electrophoresis with the GeneScan 500 LIZ standard on the ABI 3130 genetic analyzer (Applied Biosystems). The fragments were analyzed with the GeneMapper 4.0 software (Applied Biosystems).

The data analysis included AMOVA (software GenAlEx V.6.0). Locus-wise population differentiation tests were performed with software PowerMarker V. 3.0. The population genetic differences were investigated by the aid of UPGMA clustering based on the Reynolds et al. (1983) multilocus genetic distance (suitable for small sample sizes) calculated from the allele frequencies (software PowerMarker V. 3.0).
Results and Discussion

At the mtDNA locus two alleles were found: the most common among the populations studied – the 300 bp allele and less common the 295 bp allele. From the earlier region-wide studies the 300 bp allele is know to represent the multiple refugia in the southern Europe and the 295 bp allele is attributable to the northern refugium south-west of the Ural mountains (Neydenov et al. 2007, Buchovska et al. 2013). The share of the northern 295 bp allele is therefore, of special interest to reveal the populations possibly originating from the northern refugium and representing a genetically distinct line. In our material, however, the 295 bp allele was more or less equally represented by the four populations with a tendency of slightly greater share in the east-most populations in our material Višakio Ruda and Labanoras (Fig. 1). This tendency well fits with our earlier study where the greatest concentration of the 295 bp allele was found in central part of European Russia (Buchovska et al. 2013, also supported by Neydenov et al. 2007). We also assume that greater population sizes are needed to reveal the geographical patterns of the 295 bp allele distribution within Lithuania.

Figure 1. Percentage of the northern 295 bp allele in the populations studied

All the cpSSR loci studied were polymorphic providing 3 alleles (locus PCP26106) to 7 alleles (locus PCP45071). However, the significant population differentiation was obtained for locus Ptx30204 only (close to significant for locus PCP30277). Thus, if a selection of loci is needed for large data sets, the above mentioned two loci could be considered. The AMOVA on the cpSSR data revealed significant overall population differentiation (PhiPT index was 0.25 with the p value of 0.01 after 10000 permutations). The greatest part of the polymorphism at the cpSSR loci was among individuals within populations (Table 1). However, a comparably great share of the among population variation was observed amounting to 25 % of the total (Table 1).

Table 1. Results of AMOVA based on the cpSSR polymorphism

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>SS</th>
<th>MS</th>
<th>Est. Var.</th>
<th>% Var.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Among Pops</td>
<td>3</td>
<td>360033</td>
<td>120011</td>
<td>9112</td>
<td>25%</td>
</tr>
<tr>
<td>Within Pops</td>
<td>37</td>
<td>986740</td>
<td>26669</td>
<td>26669</td>
<td>75%</td>
</tr>
<tr>
<td>Total</td>
<td>40</td>
<td>1346773</td>
<td>35781</td>
<td></td>
<td>100%</td>
</tr>
</tbody>
</table>

The allele number at the nSSR loci was ranging from 7 to 14 alleles (locus SP7_14), what is much greater than at the cpSSR loci. Also the nSSR loci were more effective in revealing the population differentiation than cpSSR loci - that is 3 loci had significant population differentiation values (the loci SP11_5, SP11_7, SP11_6a). The ANOVA showed no significant overall population differentiation based on $R_{ST}$ fixation index (p=0.11) and significant differentiation based on $F_{ST}$ fixation index (p=0.05). This indicates that for the nSSR loci included in our study, the variation in allele type was more important than in allele size as regards differences among populations. The AMOVA based share of variation among the populations was much lower than for the cpSSR loci and amounted to 5 %, the rest being the variation within an individual and among individuals within populations (Table 2). Therefore, the Rit (within individual) and Ris fixation indexes were close to 1 and highly significant.

Table 2. Results of AMOVA based on the nSSR polymorphism

<table>
<thead>
<tr>
<th>Source</th>
<th>DF</th>
<th>SS</th>
<th>MS</th>
<th>Est. Var.</th>
<th>% Var.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Among Pops</td>
<td>3</td>
<td>339966</td>
<td>113322</td>
<td>2053</td>
<td>5%</td>
</tr>
<tr>
<td>Among Indiv</td>
<td>30</td>
<td>2373237</td>
<td>79108</td>
<td>39164</td>
<td>93%</td>
</tr>
<tr>
<td>Within Indiv</td>
<td>34</td>
<td>26484</td>
<td>779</td>
<td>779</td>
<td>2%</td>
</tr>
<tr>
<td>Total</td>
<td>67</td>
<td>2739686</td>
<td>41996</td>
<td></td>
<td>100%</td>
</tr>
</tbody>
</table>
For the cpSSR loci, the multilocus clustering based on the Reynolds et al. (1983) genetic distance revealed greater similarity between the western Lithuanian populations of Mažeikiai and Juodkrantė and genetic separation of central Lithuanian population of Višakio Rūda. The eastern Labanoras population was more similar to the western populations than to the Višakio Rūda population from the central part of the country (Fig. 2). Višakio Rūda population was also distinguishing by a relatively higher proportion of the mtDNA 295bp allele (Fig. 1). cpSSRs being the uniparental markers transmitted without recombination largely reflect the evolutionary history and indicate zones of shared gene pool (Neatle and Sederoff 1989). Our cpSSR analysis indicates separation of the central Lithuanian Višakio Rūda population and leads to a hypothesis of different evolutionary history of Lithuanian populations, especially bearing in mind the two distinct mtDNA alleles found in our material (Fig. 1). A more detail investigation with markedly greater population sizes could test this hypothesis. Regarding the regions of provenance, our cpSSR data indicate that the narrow strip of the sea-side lowland could be merged with the western (sea-side) highland and central Lithuania (Višakio Rūda) can be kept separate from the western part.

For the nSSR loci, the multilocus clustering based on the Reynolds et al. (1983) genetic distance return slightly different result than for the cpSSR data (Fig. 3). The sea-side Juodkrantė population was now outstanding, the Višakio Rūda population was still separable for the remaining populations of Mažeikiai and Labanoras forming a separate cluster (Fig. 3). nSSRs markers may better reflect the present-day adaptation than cpSSR markers (Tollefsrud et al. 2009, Buchovska et al 2013). A possible interpretation of our result with the nSSR loci could be that the two populations of Mazeikiai and Labanoras representing relatively colder climate were assigned into one cluster (northern highland - Mažeikiai and eastern continental highland- Labanoras). Another explanation could be the random reversible mode of nSSR mutation leading to a random differentiation based on the neutral markers (Vendramin et al 1998). In any case, a more detail investigation needed.

In summary, our study showed a significant population differentiation especially at the cpSSR loci within Lithuania with geographically interpretable patterns and provided the background for a more detail investigation based on a selection of the loci studied. The loci with relatively higher efficiency to reveal population differences were indentified for further study with much larger material.

![Dendrogram](Fig_3.png)

**Fig. 3. Results of the multilocus clustering- the UPGMA dendrogram based on Reynolds (1983) genetic distance among populations for the cpSSR data (upper plot) and the nSSR data (lower plot).**

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A Methodological Approach for Assessment of the Spatial Genetic Structure Within Scots Pine Stands Based on DNA Markers

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Abstract

The objective of our study was to test the suitability of several main spatial analysis methods to detect spatial genetic structure in Scots pine stands. We used a sub-set of 47 trees representing a sub-plot of 0.5 ha within a large sample plot selected within a 200-year-old Scots pine stand of natural origin in Punia in central Lithuania. We used 11 nSSR loci to estimate the genetic distance between the 47 trees. The analysis included: PCA, the Mantel test, spatial autocorrelation tests and Bayesian clustering. The results of this pilot study indicate that for well spatially uniform clusters, spatial autocorrelation and Mantel tests may detect the spatial structure, but for highly overlapping structures we suggest Bayesian clustering. Regarding the spatial structure with the subplot of 47 trees selected for this study, 9 highly overlapping clusters were obtained with Bayesian clustering. Our preliminary conclusion is that the spatial genetic structure in natural Scots pine stands is complex and there is an indication of highly intermixed structures, probably a consequence of multiple establishment events.

Key-words: Bayesian, genetic diversity, non-parametric genetic tests, Pinus sylvestris, spatial statistics.

Introduction

The high genetic stability of new forests became highly relevant issue and an important measure for improving the overall sustainability of new forests in the light of rapid climatic change (Eriksson et al. 1993; Savolainen et al. 2007). Genetic stability of the new forests requires the understanding of the genetic patterns of natural establishment history and evolution of genetic diversity in natural forests (Namkoong 1981; Boshier and Amaral 2005; Hayden et al. 2011). Spatial genetic structure of natural forest stands is one of the key elements in understanding the mode of natural functioning of forests from the genetic point of view (Epperson 1992; Chybicki et al. 2007). This new knowledge may provide information on how to adjust the traditional silvicultural treatments to raise the overall sustainability and return to close-to-natural forest management practices. These issues are of particular relevance for the forest tree species of high ecological significance such as Scots pine (Namkoong et al. 2002; Eriksson et al. 2003).

The first spatial genetic structure studies were mainly carried out on conifers by using isoenzymes and suggested weak spatial structure in adult stands (Epperson and Alland 1989; Epperson and Chung 2001). Recent studies on the spatial genetic structure of coniferous stands in some cases employing the more powerful Bayesian clustering methods were able to identify genetic clusters with sizes from 5 to 50 m., suggesting the effects of limited seed dispersal and that clusters have similar genetic background (Vornam et al. 2004; Cavers et al., 2005; Chybicki et al. 2008; Garcia-Gil et al. 2009). However, the results were variable and depend on the species and stand history as well as the establishment method of the stands.

Detection of spatial genetic structure based on DNA marker data requires specific statistical methods suited for binary or categorical molecular variables and employing non-parametric statistical hypothesis testing approaches such as bootstrapping and permutation (Epperson 1995; 2004; Peakall and Smouse 2006). Most of these methods require special statically software, often written specially for certain statistical procedures and being time consuming for handling large data sets, because of specific data formatting and running options (e.g. Double et al. 2005, Corander et al. 2008a).

Our approach was to start with exploratory analysis with a small subset of the data and to test a series of statistical procedures. The objective of our study was to test the suitability of several main spatial analysis methods to detect spatial genetic structure in Scots pine stands.

Material and Methods

Wood samples from 47 Scots pine trees of age ca. 200 years were sampled within an area of 0.5 ha representing a sub-plot of a large sample plot selected within an overmature Scots pine stand in Punia strict nature reserve (central Lithuania) and used as a subset for this methodological study. The stand is of natural origin consisting of a single age class of the overmature Scots pine trees and a Norway spruce understory. The spatial coordinates of each sampled tree were recorded with 0.5 m precision. The wood chips for DNA extraction were sampled by drilling with an electrical drill using 5 mm bores up to 5 cm depth into stem. DNA was extracted from wood. DNA - extraction was performed using the ATMB method following Dumolin et al. (1995). 11 nuclear microsatellite loci were used. The length of the PCR fragments was determined by using an automated sequencer (CEQ8000 Beckman-Coulter). We examined the spatial structure with all 11 nSSR loci altogether (multilocus) and locus-wise as well as by locus groups (PSYL, SPAC and PTTX). The loci are described in Table 1.
The first exploratory part of spatial structure analysis was carried out by the aid of the Principal component analysis, Mantel test for matrix correspondence and spatial autocorrelation procedures implemented in the genetic analysis software GenAlEx version 6.4 (Peakall and Smouse 2006). All these procedures start with the genetic and geographic distance matrixes among the individuals. Our analysis was based on the codominant genotypic distance considering the within-individual genetic variation (heterozygosity) (Smouse and Peakall 1999). A number of alternative genetic distances were calculated with the MSA software (ref.) and used to verify the results.

The autocorrelation coefficient $r$ computed in Spatial autocorrelation analysis framework in GenAlEx software provides a measure of the genetic similarity between the pairs of individuals whose geographic separation falls within the specified distance class. Distance classes are needed to calculated connections within the specified distance classes (e.g. pairwise connections < than 1 meter apart of each tree; then 1-2 meters apart, then 2-3 meters apart of each tree). The non-parametric statistical tests are straightforward. The null hypothesis assumes random distribution of genotypes in space ($r = 0$) and is tested by permutations which sample individuals at random (independently of their geographic distance). To reject H0, the observed $r$ values as to be greater than $r_p$ in not less than 95% of the permutations (the 0.05 significance level). Otherwise, we cannot reject the H0 that genotypes are randomly distributed in space. Then given the 1000 permutations, the permuted spatial autocorrelation coefficients ($r_p$) are sorted in increasing order and the values of $r_p$ ranked as 25th and 975th are taken as the lower and the upper bounds of the 95% confidence limit and are plotted in the plot (see below). If the observed $r$ exceeded these confidence limits for non-significance, then the spatial autocorrelation is significant. Both global spatial autocorrelation, including data from entire site, and local 2D spatial autocorrelation, analyzing parts of the data by the user defined spatial (local) groups, were carried out. The 2D local analysis better suits the data with patchy and complex spatial patterns (Double et al. 2005).

In addition, the optimum number of clusters was investigated by the Bayesian analysis of population structure implemented the BAPS software version 5.3 (Corander et al. 2008a). Both non-spatial and spatial group genetic mixture analysis was applied to individuals. For the spatial option, the geographical location of the populations is considered in the clustering by assigning the biologically relevant non-uniform prior distribution over the space of clustering solutions under expectation that underlying clusters are spatially smooth to certain degree (Corander et al. 2008b). The methods use a Markov chain Monte Carlo simulation method to group populations into optimum number of groups K, where multiple maximum K values were tested from 1 to 5 (each value repeated 3 times for verification). What BAPS does for each K value (even the replicates of the same value) is to find the optimal partitions with K less than the maximum K set by the user and after all the K values have been processed, it returns the clustering solution with the greatest marginal log-likelihood ratio value.

Results and discussion

Except of the locus PSYL25, all the remaining loci were polymorphic, providing 5 to 27 alleles in the population of 47 trees spread over ca. 0.5 ha area within a single forest stand. The loci SPAC7.14 and SPAC12.5 were most
polymorphic with 27 and 25 alleles, respectively (Table 1). The alleles combined into multilocus genotypes private for each tree. This indicates that the set of 10 nSSR loci can be used to identify individual genotypes.

### Table 1. Description of the nuclear microsatellite (nSSR) loci used. The diversity statistics is from the 47 trees from the sub-plot established within the natural Scots pine stand.

<table>
<thead>
<tr>
<th>Locus name</th>
<th>Het. observed</th>
<th>Het. expected</th>
<th>Var. repeat number</th>
<th>Min. allele</th>
<th>Mean allele</th>
<th>Max. allele</th>
<th>Num. alleles</th>
<th>Hs Nei</th>
<th>Fis, Pop</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spac7.14</td>
<td>0.89</td>
<td>0.96</td>
<td>52.52</td>
<td>181</td>
<td>207.87</td>
<td>241</td>
<td>27</td>
<td>0.95</td>
<td>0.06</td>
</tr>
<tr>
<td>psyl117</td>
<td>0.53</td>
<td>0.53</td>
<td>0.70</td>
<td>191</td>
<td>199.97</td>
<td>209</td>
<td>7</td>
<td>0.53</td>
<td>-0.01</td>
</tr>
<tr>
<td>psyl12</td>
<td>0.30</td>
<td>0.31</td>
<td>0.31</td>
<td>200</td>
<td>207.62</td>
<td>210</td>
<td>4</td>
<td>0.30</td>
<td>0.02</td>
</tr>
<tr>
<td>psyl118</td>
<td>0.09</td>
<td>0.08</td>
<td>0.16</td>
<td>297</td>
<td>300.16</td>
<td>309</td>
<td>5</td>
<td>0.08</td>
<td>-0.02</td>
</tr>
<tr>
<td>psyl42</td>
<td>0.72</td>
<td>0.72</td>
<td>2.68</td>
<td>167</td>
<td>171.47</td>
<td>175</td>
<td>4</td>
<td>0.72</td>
<td>-0.01</td>
</tr>
<tr>
<td>psyl25</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>221</td>
<td>221.00</td>
<td>221</td>
<td>1</td>
<td>n.d.</td>
<td>n.d.</td>
</tr>
<tr>
<td>Spac12.5</td>
<td>0.87</td>
<td>0.93</td>
<td>37.24</td>
<td>121</td>
<td>152.43</td>
<td>193</td>
<td>25</td>
<td>0.93</td>
<td>0.06</td>
</tr>
<tr>
<td>Spac11.4</td>
<td>0.87</td>
<td>0.86</td>
<td>14.52</td>
<td>139</td>
<td>146.64</td>
<td>169</td>
<td>12</td>
<td>0.85</td>
<td>-0.02</td>
</tr>
<tr>
<td>PtTX4011</td>
<td>0.47</td>
<td>0.66</td>
<td>5.37</td>
<td>259</td>
<td>262.28</td>
<td>281</td>
<td>5</td>
<td>0.66</td>
<td>0.29</td>
</tr>
<tr>
<td>PtTX4001</td>
<td>0.79</td>
<td>0.75</td>
<td>8.96</td>
<td>201</td>
<td>215.96</td>
<td>229</td>
<td>12</td>
<td>0.74</td>
<td>-0.06</td>
</tr>
<tr>
<td>psyl16</td>
<td>0.68</td>
<td>0.81</td>
<td>2.39</td>
<td>198</td>
<td>202.09</td>
<td>208</td>
<td>6</td>
<td>0.81</td>
<td>0.16</td>
</tr>
</tbody>
</table>

The first step was to carry out the PCA analysis of the molecular data and visually compare the spatial distribution of trees within the stand with the distribution against the two main principal components from the PCA analysis of the molecular data. The visual examination revealed certain trends of association between the genetic and spatial distances (Fig. 2). For instance, trees 1, 2 and trees 47, 48, 45 forming spatially compact clusters of were also located closer than the more distant trees in the genetic space (Fig. 2). However, the PCR and spatial plots also indicate a complex structure and the genetic clusters, which may not have a clear border but are rather overlapping. This may complicate the classical spatial correlation tests producing correlation statistics such as correlation coefficient, which may fail to detect significant associations if local nature in the heavily overlapping structures (Double et al. 2005). A way to solve this problem can be the plots of spatial arrangement of statically separable groups (clusters) depicted in two dimensional plots.

The Mantel test for association between the multilocus codominant genetic distance between the genotypes (codominant option in the distance menu of GenAlEx) and the spatial distance between the genotypes revealed close to significant relationship \((r = -0.1, p = 0.08)\). However, the correlation was negative, indicating stronger genetic associations with increasing distance between the trees. This means that it is probable that the spatial clusters are larger than the group of neighbouring trees and it may increase until certain distance threshold, which may reflect the spatial group. Furthermore, as for the PCA results, the negative correlation in the Mantel test indicate highly overlapping structures. In addition, the Mantel tests return a linear correlation coefficient over entire site, while the relationship based on the geographical distance in a highly overlapping structure may not be linear. From the other range of the genetic distances tested by the Mantel test the Nei (1978) genetic distance corrected for the small sample size (abbreviated as DSG in MSA software) returned also negative and strongest correlation coefficient \((r = 0.12, p = 0.06)\). Mantel test by loci groups showed significant negative correlation for the 5 PSYL loci \((r = -0.11; p = 0.02)\) and non-significant for the PTTX and SPAC loci.

Given the indications of the complex spatial genetic structure retuned by the PCR and the Mantel test, we further employed the spatial autocorrelation analysis framework available in GenAlEx software. The global spatial
autocorrelation test calculates the correlation coefficient as a measure of the pairwise genetic association between the trees within a specified distance classes (e.g. for trees which are 1 to 3 m apart from each other than 3 to 6 m apart from each other and etc.). Following the calculation mode based on the distance classes and assuming little overlapping, the distance class at which the estimate of the correlation coefficient is no longer significant provides an approximation of size of spatial genetic clusters (Peakall et al. 2003). However, the choice of the distance class size requires attention because too small size leads to a low statistical power (low \( n \) in Table 2) and too large distance step may miss significant genetic relationships (Peakall and Smouse 2006).

Table 2. The results of the spatial autocorrelation analysis based on codominant genetic distance available in GenAlEx software. \( n \) is number of pairwise comparisons. The confidence intervals and \( P \) values are obtained by 1000 permutation tests.

<table>
<thead>
<tr>
<th>Distance Class (end point)</th>
<th>n</th>
<th>59</th>
<th>123</th>
<th>186</th>
<th>213</th>
<th>180</th>
<th>119</th>
<th>87</th>
<th>58</th>
<th>36</th>
<th>13</th>
</tr>
</thead>
<tbody>
<tr>
<td>Correlation coefficient ( r )</td>
<td>0.019</td>
<td>0.006</td>
<td>-0.016</td>
<td>-0.003</td>
<td>0.011</td>
<td>0.001</td>
<td>-0.003</td>
<td>0.000</td>
<td>0.001</td>
<td>-0.014</td>
<td></td>
</tr>
<tr>
<td>Upper 95% confidence limit</td>
<td>0.026</td>
<td>0.021</td>
<td>0.021</td>
<td>0.017</td>
<td>0.019</td>
<td>0.027</td>
<td>0.024</td>
<td>0.034</td>
<td>0.036</td>
<td>0.073</td>
<td></td>
</tr>
<tr>
<td>Lower 95% confidence limit</td>
<td>-0.040</td>
<td>-0.023</td>
<td>-0.018</td>
<td>-0.021</td>
<td>-0.024</td>
<td>-0.025</td>
<td>-0.030</td>
<td>-0.038</td>
<td>-0.042</td>
<td>-0.073</td>
<td></td>
</tr>
<tr>
<td>( P(r-rand &gt;= r-data) )</td>
<td>0.130</td>
<td>0.410</td>
<td>0.970</td>
<td>0.640</td>
<td>0.090</td>
<td>0.500</td>
<td>0.600</td>
<td>0.480</td>
<td>0.560</td>
<td>0.670</td>
<td></td>
</tr>
<tr>
<td>Mean Bootstrap ( r )</td>
<td>0.018</td>
<td>0.006</td>
<td>-0.017</td>
<td>-0.003</td>
<td>0.013</td>
<td>0.000</td>
<td>-0.003</td>
<td>0.002</td>
<td>0.003</td>
<td>-0.012</td>
<td></td>
</tr>
<tr>
<td>( U )</td>
<td>0.058</td>
<td>0.030</td>
<td>0.005</td>
<td>0.017</td>
<td>0.032</td>
<td>0.025</td>
<td>0.024</td>
<td>0.043</td>
<td>0.041</td>
<td>0.046</td>
<td></td>
</tr>
<tr>
<td>( L )</td>
<td>-0.023</td>
<td>-0.026</td>
<td>-0.037</td>
<td>-0.024</td>
<td>-0.008</td>
<td>-0.027</td>
<td>-0.037</td>
<td>-0.046</td>
<td>-0.041</td>
<td>-0.087</td>
<td></td>
</tr>
</tbody>
</table>

Value of x-axis Intercept by the \( r \) curve 6.768

We experimented with variable distance class sizes of 1, 2, and 4 meters, where the total distance to the most distant tree was 35 meters in our sample plot. The results based on the codominant genetic distance available in GenAlEx software revealed no significant spatial correlation coefficients (\( r \)) at any of the geographic distance classes: (a) the significance tests of \( r \) based on 1000 permutations returned no significant probability to reject the null hypothesis that the permuted \( r \) is equal or greater than the observed \( r \) (see the row \( P(r-rand >= r-data) \) in Table 2; (b) none of the observed \( r \) exceeded the upper and lower confidence limits for significant \( r \) based on 1000 permutations and 1000 bootstraps. The values of the autocorrelation coefficient varied strongly with increasing distance classes and were within the limits of correlations obtained by Chybicki et al. (2008) on spatial structure of Scots pine (Fig. 1).

However, interesting tendency was observed where the spatial autocorrelation coefficient reached a close to significant value at the distance class from 12 to 15 meters (the highlighted \( p \) in Table 2). Similarly, the spatial autocorrelation analysis with the Goldstein et al. (1995) SSR genetic distance indicated increase and subsequent drop of \( r \) at the distance class of 12 to 14 meters (Fig. 3). The corresponding peaks of \( r \) at the distance class of 12 to 16 meters were observed with most of the other genetic distances tested. Locus-wise spatial correlation coefficients were variable but not significant, some, however, producing significant associations between trees 20 m apart (locus PSY18, not shown), but for most loci except the monomorphic one, the increase of spatial autocorrelations at the distance of 12 to 18 meters was observed (especially for the PTXX loci, not shown). The first x-intercept of \( r \) in the plot of \( r \) as a function of distance class (Fig. 2) is known to indicate possible genetic patch size (Peakall et al. 2003). However, in our case where the \( r \) were variable with multiple x axis intercepts, it may be not as good indicator of genetic patch size (Fig. 3). The x intercept also varied much depending on the number of distance classes (higher number, greater intercept) in agreement with Peakall et al. 2003. We interpret the \( r \) values at the distance class of 1 to 2 or 3 meters caution, as there were only a few trees sampled so close.
Our further analysis focused on local spatial autocorrelation across 2 dimensional landscape (Double et al. 2005) implemented in the GeAlEx software. This method allows detecting a finer scale spatial structure where individual spatial arrangement is patchy with larger gaps. It uses sampling strategy where a subset of points surrounding a pivotal data point is compared. This local subset of points includes an individual and its $n$ nearest neighbours, where $n$ is defined by the user. For each subset, a local autocorrelation ($l_r$) is estimated based on $n$ pairwise comparisons between the pivotal individual and its $n$ nearest neighbors. The complete analysis consist of $l_r$ from a series of subsets differing form each other by increasing number of the nearest neighbors. It differs from the global spatial autocorrelation in the way the individuals are selected for calculating $l_r$, where the local subset can be viewed as specially constructed distance class (Double et al. 2005).

Figure 4. Results of the 2d local spatial autocorrelation analysis indicating trees that had significant association with at least 2 nearest neighbours (left plot) and with at least 7 nearest neighbours (right plot)

The result of the 2d local spatial autocorrelation analysis showed that the greatest number of the individuals with significant associations was obtained for the nearest 2 and nearest 7 neighbouring individuals (Fig. 4). This indicates presence of at least 3 genetically distinct groups: one in the upper right corner of the site (indicated by the “plus” signs on the right plot in Fig. 4) and the other in the lower left corner of the site on the same Fig. 4 plot). There could be more groups but these are not separable by this method.

In the first run of the BAPS Bayesian clustering with non-spatial option, we let the $K$ value (expected number of clusters) to vary freely in order to objectively let the program to identify the best partition based on highest log(ml) values. We also placed an upper bound of 10 partitions ($K$ not larger than 10) based on the area of the sample plot (0.5 ha and the spacing of trees of approx. 8 × 8 meters). With this option, BAPS searches for the portions with the greats log(ml) value and returns best solution. The result of the clustering returned the optimum number of 9 clusters (probability of 9 clusters was 1.0 and the partition of 9 clusters possessed the highest and log(ml) value) (Table 3, Fig. 5, left plot). The spatial arrangement of the 9 clusters was very overlapping with no well spatially separable and uniform clusters (Fig. 5, left). Then, we forced to return a 5 cluster structure by setting the $K$ value fixed to 5. The resulting 5 cluster partition has a lower log(ml) value than the 9 cluster partition (Table 3). However, the spatial arrangement of the 5 cluster was less confusing with main 3 groups still being very much overlapping (Fig. 5, right). In attempt to for a further search of more consistent structuring, we UPGMA clustered the 9 BAPS clusters by Nei’s genetic distance (the UPGMA clustering was done in BAPS software, Fig. 5, left) and depicted the major groups of clusters in the spatial plot (Fig. 5, right). The structure still seems overlapping; with a tendency of group 2 located at the upper part of the sub-plot (Fig. 6).

The spatial clustering of individuals in BAPS software indicated rather uniform spatial structure and with free $K$ returned one cluster only (not shown). Then we tested a range of fixed $K$ values from 3 to 20 and all these analyses did not distinguish groups but rather allocated single trees into own groups (Fig. 7). This indicates very much overlapping structure as confirmed by the non-spatial BAPS analysis and in such case the above described non-spatial methods can be considered.

Evidently, the BAPS Bayesian clustering was much more effective in revealing the genetic spatial structure than the Mantel test and the spatial autocorrelation tests. We suggest employing the later methods for exploratory purposes and less overlapping structures. The results of BAPS clustering suggest very variable genetic sources of natural self-establishment of such over-mature natural stands retaining a rather random and overlapping genetic structure. A logical evolutionary interpretation of our result is that related individuals after such a random natural establishment pattern do not occur in pure clusters but rather are intermixed with less related individuals and this may lower the inbreeding level in the progeny (Karkkainen and Savolainen 1993). However, more research on larger areas and several replicated stands are needed to confirm these presumptions. Stand management and events after establishment may also markedly affect the remaining genetic structure (Neale 1985; Takashi et al. 2000; Finkeldey and Ziehe, 2004).
Table 3. Cluster structure obtained with two methods of non-spatial Bayesian clustering with BAPS software (tree ids are given in the parenthesis)

<table>
<thead>
<tr>
<th>Best partition BAPS clustering with free K non-spatial option (log(ml)= -1722.72)</th>
<th>BAPS clustering with fixed K =5 and non-spatial option (log(ml)= -1715.07)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cluster 1: {2, 10, 11, 15, 40, 45}</td>
<td>Cluster 1: {5, 28}</td>
</tr>
<tr>
<td>Cluster 2: {16, 20, 22, 33}</td>
<td>Cluster 2: {4, 6, 9, 13, 24, 27, 35, 39}</td>
</tr>
<tr>
<td>Cluster 3: {5, 32}</td>
<td>Cluster 3: {1, 19, 32, 36, 41, 44, 46}</td>
</tr>
<tr>
<td>Cluster 4: {35}</td>
<td>Cluster 4: {3}</td>
</tr>
<tr>
<td>Cluster 5: {1, 19, 25, 36, 41, 44, 46, 47}</td>
<td>Cluster 5: {2, 7, 8, 10, 11, 12, 14, 15, 16, 17, 18, 20, 21, 22, 23, 25, 26, 29, 30, 31, 33, 34, 37, 38, 40, 42, 43, 45, 47}</td>
</tr>
<tr>
<td>Cluster 6: {6, 9, 12, 13, 24, 37, 39}</td>
<td></td>
</tr>
<tr>
<td>Cluster 7: {3, 8, 18, 29, 30, 31, 34, 43}</td>
<td></td>
</tr>
<tr>
<td>Cluster 8: {7, 14, 17, 23, 26, 28, 42}</td>
<td></td>
</tr>
<tr>
<td>Cluster 9: {4, 21, 27, 38}</td>
<td></td>
</tr>
</tbody>
</table>

Figure 5. Results of the BAPS Bayesian clustering analysis shows (left plot) the clusters identified by the non-spatial option with the free number of partitions (K) allowing an objective determination of the optimum number of clusters and (right plot) non-spatial clustering with fixed K value to 5 clusters which forced BAPS to return 5 clusters.

Figure 6. The results of UPGMA clustering of the 9 BAPS clusters (the spatial arrangement of these 9 BAPS clusters are shown in the right plot) by Nei’s genetic distance. The following UPGMA groups were obtained: group 1 (BAPS clusters 5, 6, 7, 8), group 2 (BAPS clusters 3 and 9) and group 3 (BAPS clusters 1, 2, 4). The UPGMA groups are spatially plotted in the plot to the right, where the led end indicates the UPGAM groups.
In conclusion, there an indication of a complex spatial genetic structure in natural Scots pine stands with of highly intermixed structures, probably a consequence of multiple establishment events. To statically detect and interpret such mixed structure Bayesian cluster and spatial plots of clusters are more informative than spatial autocorrelation analysis approach.

Figure 7. Results of spatial BAPS clustering, of individuals within the stand where the spatial location of the trees is considered when estimating the optimum partitions of individuals within each cluster. The 5 and 12 cluster structure is given in the left and right plot, respectively.

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References

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Abstract

The given publication discloses a search for objective vision on definition of concept, goal and practicable steps regarding the achievement of desired land reform in Ukraine. Besides, it also justifies some economic constituents under the conditions of Ukrainian realities and calls to globalization. It is identified that integrated and system uniting national regulatory policy, as related to all concerned categories of lands and all natural resources being implemented in legal, economic, environmental, social, and in spiritual planes, is the key policy in order to make progress and accomplishment of desired land reform in Ukraine. It is considered that introduction of mechanisms on determination and functioning of partitioned profits (income) on a new rental basis will stimulate the objectification of price for land shares and natural resources being in use, and provide the social protection as in the case of owners and users. The first part of profits which is a priority for the State and is distinguished from others would require a special attention. It is advisable, depending on the proposed vision regarding the execution of desired land reform in Ukraine, that the National (State) Concept and Programs have to be developed and approved legislatively coupled with all these urgent measures. As this takes place the development, approval and realization of non-departmental state regional and local projects on land use and nature management (essential for all partners to implementation) are due to be fulfilled.

Introduction

For the most part, the land reform in Ukraine was minimized to agrarian one and initially to transfer of land assigned for agricultural purposes into the ownership of farfetched collective property. Later on, the fertile land sharing into lots, as well as accelerated reforming of collective agricultural enterprises took place, so that to reorganize them into a kind of more efficient market-oriented farms. As this takes place, the rate of such unusual transformations passed ahead of reform process in economic, financial, customs and other important fields of the new Independent Ukrainian State.

In other states postsovetskiy land and agrarian reforms took place in the second scheme. For example, in Lithuania, land privatization in rural areas is executed by formation of land parcels in compliance with the land management plans for the land reform. Following the procedure prescribed by legal acts the requests for restitution of land filed by applicants are registered (including enclosed documents), the land parcels are formed and approved during the meeting of applicants. After the land management plans for the land reform are approved, the cadastral data are prepared that are necessary for the land sale-purchase transactions or for the adoption of decisions regarding the restoration of ownership rights to land, also other documents are prepared necessary for legal registration of land parcels in the Real Property Register (Aleknavičius, Pranas et al., 2005).

In particular, contrary to the declaration on alleged possibility for peasants to make a voluntary and free choice of farming different kinds (e.g., private households of European model on a basis of virtual mutual ownership) it was found to be unrealizable. Absolutely inconsistency was lacking and, unfortunately, is still in progress in the political circles and power structures to gain a greater vision of outlook for the State development. The extremely large corporate business agrarian structures of export orientation (agricultural holdings with a total area of about 100-200 thousand hectares and more), practically, without taking into account the national interests, in the course of leasing, emphyteusis and other kinds of rights to use land shares came into existence. In searching for superprofit the soils were impoverished and degradated, the natural environment was polluted too. As a result, overwhelming majority of Ukrainian population is forced to fill their food baskets with inorganic, ecologically unacceptable provisions, among which there are prohibited products of dubious quality, often falsificated food-stuffs, production with chemical additives and genetically modified components. It sounds paradoxical but many of these food-stuffs are imported.

Despite this, a number of scientists believe the process of reform and development of the agro-food sector in Ukraine positive. Simultaneously, they show some problems.

By persuasion Artiushyn et al., (2011, - p.7). whereas Ukraine’s agro-food sector looked rather successful against the background of the Ukrainian economy in general, agrarian nongovernmental organisations, some politicians, and agrarian scientific institutions point to considerable problems in the sector that have been aggravated under the crisis. These concern financing and lending for all the actors of the agro-food production and sales chain, their operating performance, assets renovation and engagement of investments, expansion of sales markets, etc.

In this case Artiushin et al., (2011, - page 16) shows only: “The most significant objective is to complete land reform and lift the moratorium on sale of agricultural land. Achieving this objective envisages: securing maintenance of a uniform state land cadastre and creating a uniform state system of registration of titles for immovable property including for land plots; creating conditions for development of mortgage lending on the security of land; providing conditions for free purchase and sale of agricultural land plots”.

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However, on the other hand, under the pretext of searching the ways to improve the situation, there are many unsubstantiated discussions (over ten years) are debated at all levels of power, in the scientific circles of society, also among the population about the possibility of agriculture management in Ukraine, as soon as the following conditions are due to be achieved, namely: entering the large foreign investments and mythical subsidies; introduction of free land markets, deposits and mortgage of land lots. It is pointed out at usefulness of agriculture management, mainly by enterprises – landowners. With this aim in view, the Verkhovna Rada of Ukraine is called upon to approve the legislative act on limiting the size of real estate per landowner, for example not over 100 000 hectares. The process of term prolongation or cancellation of moratorium with regard to the buying and selling of fertile land does not promote for the necessary decisions to be adopted. With all this, the fact must be taken into account that only those who have a desire and a lot of money at disposal will become landowners. That is why such a state of matters requires a vision quest for desired land reform to be fulfilled, including the agricultural one.

In Ukraine, the study of these and other problems, including search of ways for their implementation is the object of great attention. A whole number of works are devoted to the mentioned problems. It should be pointed out such authors as: I.B. Bystryjakov, V.M. Geits, N.Ja. Demianenko, D.S. Dobriak, V.Ja. Meselyak, L.Ja. Novakovski, P.T. Sabluk, A.M. Tretiak, M.A. Khvesyk, A.M. Shpichak, V.V. Jurchishyn et al. The studies being carried out by Ukrainian scientists confirm the existence of the problems on land reform in Ukraine.

Inasmuch as these problematic issues still remain open, and the discussions will be under way, the necessity comes into being to elaborate some original integrated and system proposals regarding the further lines and methods for land reform to be achieved.

Statement of the problem
The task of this publication is a search for objective vision on definition of concepts, goals, and practicable steps regarding realization of desired land reform in Ukraine, hand in hand with substantiation of some economic constituents for its achievement under the Ukrainian realities’ conditions and calls to globalization.

The object of research is the process and consequences of land reforms and the state of natural resources in Ukraine.

Subject of research – the theoretical and methodological foundations find ways and mechanisms to balance environmental, economic and other interests in the accomplishment of reforming land relations in Ukraine.

The theoretical basis of the study is general scientific position comprehensive mix of classic modern economic theory, economics, environmental management, sustainable land use, economy, environment, governance and related them science and scientific works of domestic and foreign scholars.

The methodological basis of research methods are used as the empirical and theoretical levels, namely: inductive and deductive (in the study, analyze, organize and process information); conceptualize problems and clarify certain concepts (the study of the problems and their causes); historical (the study of trends and land reform, and in the use of natural resources); monographic, abstract logic (the development of scientific principles and mechanisms of the theoretical foundations of the modern vision of the future use of land and its natural resources - the main national wealth Ukraine); conceptualize (the study of problems and clarify some consequences of reform and of events); current hypotheses (in developing strategies and to determine the main priorities of the formation of national environmental-economic models in agricultural landscapes from the perspective of balancing different interests - as a paradigm of the ultimate goal achievements of land reform in Ukraine).

Research results
During the process of reforms which are in progress in Ukraine, the requirements on maintenance and supporting of a number of positive attainments in science and agricultural production, as had been embodied at the years of the Soviet Ukraine remained beyond the field of vision. Unfortunately, the necessary analysis and assessment, forecasting and planning, financial and long-term credit support, technical and technological modernization, as well as development and support of social sphere functioning, creation of new work stations along with employment ensuring for able to work population - all these had not been executed and such the situation is indeed at present.

Reasoning from these investigations it may be concluded that all reforms in these walks of life in Ukraine were limited to a known "divide and possess". As a result, there were divided among the peasants about 27 million hectares of fertile lands into nearly seven million pieces-shares. According to the operative information obtained as a consequence of carried-out work by the Ministry of Agrarian Policy of Ukraine, the 96% of the fertile were divided by the end of 2005 into the shares of land, which is 26.8 million hectares. In the course of such reforms, more than 16 thousand new agroformations were created based on 11.3 thousand collective farms. Among them: limited liability companies, joint stock companies, cooperatives, private and individual farms, and others, that began to use the land and property on the tenant right. In addition, there were about 43 thousand farms (created earlier) occupying 4.3 million hectares for land use and more than 4 million individual peasant farms, land use of which comes to more than 6 million hectares.
Thereafter the process of big business entering into the agricultural sector of economics has increased. By expert appraisal, despite the putting the moratorium in force in Ukraine since 2002 on buying and selling of agricultural land, there is over five million hectares of appropriated fertile land by way of different shadow schemes, including by companies with foreign capital.

It is reasonably to consider such a situation as consistent phenomenon, because the transformation of land relations took place outside the scientifically grounded comprehensive and system land management process. The reform itself was not accompanied by a complex of works according to the law of national land management that is the only and main instrument for balancing of all interests, especially national ones. Indeed, such kind of works should cover the spectrum of features of one or other territory and find a balanced decision in the legal, ecological, economic, social, and spiritual planes, while taking into account the spatial and time realities and global calls. However, the integral effective economic units even had not come into developing, the problems of soil fertility improving and environmental protection were not under resolving. The same was true for many other problems. The high-precision digital mapping was not carried out, geographic information, land cadastre, land registration and other systems were not hold.

As a consequence, owing to lack of scientifically grounded vision of the prospects for development of specific territories and the Ukrainian State in a whole, the real mechanisms of economic and agricultural transformation were unavailable, and the civilized local government is nonexistent. The predicted production and creation of necessary conditions for valuable feeding of population remain to be unchanged problem. The foodstuffs in Ukraine must be natural, organic and ecologically clean products.

Analyzing the state of continued looking for desired ways for reforms to be in progress and some ways out from the existing situation throughout the course of transformation period in Ukraine, it is pertinent to note as a positive fact that, there are many supporters of such judgments to date, due to numerous publications, including works issued by the author of this study. Specifically, the alternative ideas, arguments and proposals were stated in the "The Voice of Ukraine" newspaper of Verkhovna Rada of Ukraine and in the "Governmental Courier" newspaper of government bodies. As this takes place, a new phenomenon should be recognized as a positive fact of origination the process of enlightenment and understanding among researchers, educators and practitioners who can speak openly to community. This process have already gave the morality positive sprouts. It is seen that in such social environment the unification process on harmonization among disparate minds concerning the identifying of concept, goals and real steps on achievement of desired land reform for the people of Ukraine.

During the course of research we have proved the fact: "The agricultural sector of economics grounded on the land use that means natural management, cannot develop independently, as other sectors of national economy, without integrated home policy". Cogent permanent factor for the unifying process will be a need to get three meals a day with domestic foodstuffs of high-quality for all Ukrainian population, regardless their ideology, habitat or place of work. Under these conditions, the main unifying ground includes the land and its natural resources which, in accordance with the Constitution of Ukraine are the property of the entire Ukrainian population, and being the national heritage are under the special state guarantee. That is why, while carrying out the desired instead of farfetched land reform in Ukraine, we consider that the key to success lies in the process of solving the existing problems concerning land relationship and natural management.

Such vision allows us to find the ways toward answers to almost all problem questions, especially those concerning the methods on implementation of economic constituent.

Since the goal of any activity is to gain profits, the commercialization of home policy in Ukraine should also be based on the same ground. The state should be directly involved in this activity in the interests of population at the national and regional levels. It must be re-emphasized once again that when possessing, using, and managing with the land, the nature management is put into practice simultaneously. These relationships are inextricably interconnected between themselves and with the territory of Ukraine. Taking into consideration the fact that only land shares are in the private property rather than land at all and its natural resources (the main national heritage), the involving of mechanisms for balanced profits (income), society interests included, such kind of land use and nature management should be based subsequently on the new rental basis.

The profits should be differentiated into the following four constituents:

I. A part of profit which is paid by all the subjects for land use and use of its natural resources (a part of the national heritage). The rate size of this constituent is determined depending on the soil capacity, water quality, flora and fauna, on the valuable properties of mineral resources, location, and other natural factors. The value of this constituent cannot be lower than the second constituent;

II. A part of profit that goes to the lot owner (State, municipal or private) as a result of personal use, or transfer it on lease or any other paid use. This profit size cannot be lower than the rate of bank interest from the real value of the land lot;

III. A part of the resulting profit owing to additional contributed labour (physical, mental, resource) as additional compensation for the thrifty management with the land and its natural resources. This part of profit remains fully at working producer and is taxation-free;

IV. A part of the resulting profit owing to monopolistic actions. These issues are regulated at the State level and are the exclusive priority of the State (in this case). Such actions are focussed to the rational and efficient use of land and its natural resources, on the development of domestic mining, production, procurement,
processing, trading and other activities, as well as on incentives of the previous constituents. All these actions are
governed by the environmental regulation.

All four constituents of profits (income) are the integral, rent-forming, interconnected between
themselves and all other participants, who are the users and consumers of the natural resources, and the State.
The mechanism of their determination and functioning should be the main and component parts at the formation
and generation of socio-economic processes. Therefore, we believe that only through implementation of
appropriate domestic regulatory policy as for use of land and its natural resources together with other activities
the possibility can arise to improve the existing socio-economic and environmental conditions and to create the
State governed by the rule of law, while providing the welfare in Ukraine.

In this case, the questions of economic of land relations and nature management are many-sided and
complex considered, also in the legal, environmental and social lines. At the same time the specified
characteristics and properties of a given territory and intended uses of each square and cubic meters of Ukrainian
land are concretized. Such nature management must be paid for all, besides the mechanism for profits to be
received and also free trade relations must act with the direct assistance of the State.

An important condition to accomplish these foreseeable results from the proposed land relations and
transparent process of nature management between all the subjects (owners and users of land and its natural
resources), and the State and local communities is the full and strictly abiding by the law of the Constitution of
Ukraine.

At the same time it is reasonable to implement the orderliness of the existing public institutions, being
relevant to the problems of land and its natural resources, also of the executive bodies of local self-government
in the fields of land relations and natural management, giving them the appropriate and consistent functional
wide powers. With this aim in view we propose to form an independent State institution in the form of the
National bank of land and nature resources of Ukraine (National Comora) as a kind of peculiar database. Such an
institution should have its own budget (Bank Budget, Rent Bank and Bank on Reconstruction and Development
of Ukraine). Unlike the other banks, it should contain the informational data and fulfil the multi-purpose
functions and tasks that are noninherent to commercial banks, including possession, use and instructions to be
realized through a new national policy of economic relations, including rental ones. It is supposed that the
identified functions of mentioned Bank will ensure the constitutional rights of all the subjects of such appointed
relations and realization of relevant Concepts and Programs, as well as will be the main generator and stimulator
in forming of the State national and local budgets.

Special status should have the Budget of the National Bank of Land and Nature Resources. It must be
formed at the expense of the part of contribution foreseen by the new Law of Ukraine "On Land Rent and Nature
Resources" and some other receipts of funds, and can not be less than the volume of measures stipulated by the
Programs for their realization.

General conclusions and proposals

The integrated and system uniting national regulatory policy, relating to all concerned categories of lands
and its all natural resources being implemented in legal, economic, environmental, social, and spiritual planes, is
the key policy in order to make a progress and accomplishment of desired land reform in Ukraine.

For realization of both the principal and the immediate measures it is reasonable to introduce the State
cadastre of land and natural resources, as well as real estate related, and also the State registration system into the
proposed National Bank system, while taking a course for creation a modern GIS and other systems.

Introduction of mechanisms on determination and functioning of partitioned profits (income) on a new
rental basis will stimulate the objectification of price for land shares and natural resources being in use, and
provide a social protection, as in the case of owners and users. The first part of profits which is the priority one
for the State and is distinguished from others would require a special attention.

In correspondence with the proposed vision regarding the achievement of the desired land reform in
Ukraine, coupled with all these urgent measures the National (State) Concept and Programs have to be
developed and approved legislatively.

As this takes place the development, approval and realization of non-departmental state regional and local
projects on land management and nature use (essential for all partners to implementation) are due to be fulfilled.
The issues of perspective and current development of all administrative territories must be settled, the general
schemes and plans of development and building of each village and settlement must be made up in such a way as
to suit the top requirements and actual problems on their realization.

During the process of development of such land management projects the following procedures should be
performed: digital precision mapping of territory, inventory and certification of land, its owners, users, and
associated legal relationships. It is proposed to design the stable and efficient new agricultural lots, above all, the
farms and those of family type coincidently with forming of minimal indivisible areas for their intended
functional purpose including the process of putting them in order and consolidation of separately used lots in
nature. The remaining large areas (fields) of cultivated land should be compact-used. They should have the
appropriate structure of production and their areas should be within the limits of territorial unit for rural local
community. The particular area is defined by the land management.
In order to remedy the situation for the optimal natural agro-wood-landscapes to be formed without unmotivated breaking (parcelling) of area, it is suggested to gauge and introduce promptly on legal grounds the mechanism whereby the first transactions and the change in the designated purposes for all the shared lots of agricultural purpose would be directly go through the government specialized institution agency (its branches). It is advisable at the same time to put owners (who has no need for lots or who is in need of money) the right to alienate (sell) his property exclusively at government’s disposal, so far as all the land shares were turned over free from the government property.

With this object in view, the present-day President, who regains the wide constitutional powers unique to the former president L.D. Kuchma, would promulgate the corresponding decree on the land reform with identifying of the concept, aims and real concrete steps on all the lines of command concerning the achievement of the desired land reform in Ukraine. In particular, this decree must contain enumeration and contents of laws for confirmation in the Parliament and the line of attack on the problem of comprehensive carrying out of required procedures and measures for implementation of the national land cadastre and the new land management. Such actions must be carried out for each reformed farm and at the same time al over the country.

Taking into account all mentioned, we believe that progress toward realization of proposed regulatory policy on accomplishment of land reform in Ukraine is dependent upon the indisputable fulfilment of such principles and conditions, namely:

- objectivity, comprehensiveness, systemness and openness;
- participation of power authorities (on all levels) and compulsory in implementation of accepted decisions;
- constant superintendence and personal responsibility for the tasks to be performed.

References


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Agricultural Runoff Monitoring in Latvia

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Abstract

Agricultural runoff monitoring in Latvia was initiated in 1994 with the aim to identify and assess the environmental effects of agricultural management practices on water quality. This paper summarizes the key components of diffuse nutrient losses in different spatial and temporal scales. The agricultural runoff monitoring system consists of three monitoring stations at Bērze, Mellupīte and Vienziemīte with hydraulic measurement structures and recording equipment. The monitoring stations are situated in different parts of Latvia and represent regions with different climatic conditions, soil texture, slopes and farming intensity. Long-term data (1995 – 2010) collected during the agricultural runoff monitoring proves that diffuse source pollution from agricultural land, i.e., nitrogen and phosphorus losses into water, depends on anthropogenic activities (intensity of agricultural practices), natural factors (meteorological and hydrological conditions), and scale of measurements (experimental plots, drainage field, small catchment, river).

Introduction

Agriculture is the dominant contributor to anthropogenic diffuse waterborne nitrogen (N) and phosphorus (P) load within the Baltic Sea catchment area (HELCOM, 2009; HELCOM, 2011). The main objectives of this study are to determine the quality of agricultural runoff based on the concentrations of nitrogen and phosphorus and to study the causes of agricultural diffuse source pollution. Agricultural runoff monitoring in Latvia is carried out in different spatial scales, i.e., experimental drainage plots, drainage field, small catchment, river. At the experimental drainage plots scale, the nutrient leaching processes in the soil are determined, depending on the type and amount of applied mineral and organic fertilizers, application timing, crop rotation and soil cultivation. Hereby, to compare nutrients concentrations at different spatial scales, normal mineral fertilization treatment plots were used. At the drainage field scale, the nutrient leaching is determined by different agricultural crop production, a varied use of fertilizers and type and timing of soil cultivation. At the small catchment scale, the total impact of agriculture on the nutrient losses in the heterogeneous catchment by a variety of farming and land use patterns, and with varying topography and soil characteristics is determined. The river scale includes research in the small (<100 km²) and mid-size catchment (100 – 1000 km²) rivers. At the small river scale (the Ālave River) the impact of dominant land use type on water quality can be evaluated, while at the mid-size river scale (the Bērze River) it is possible to determine water quality in the river outlet and subcatchments where various land use types, topographic conditions, point source pollution are found.

Materials and Methods

The diffuse pollution monitoring stations ”Bērze” (Dobele District), ”Mellupīte” (Saldus District) and ”Vienziemīte” (Jaunpiebalga District) are located in Lielupe, Venta, and Gauja river basin districts, respectively. Locations of the monitoring stations are specified in Figure 1.

Figure 1. The location of agricultural runoff monitoring sites and nitrate vulnerable zones in Latvia
According to annual interviews with farmers the Bērze monitoring site can be characterized as a relatively intensive agricultural production area compared with the present farming conditions in Latvia (N fertilizer and manure application vary among catchment fields from 51 to 224 kg ha\(^{-1}\) year\(^{-1}\), P application ranges from 24 to 66 kg ha\(^{-1}\) year\(^{-1}\)). The agricultural production in Mellupīte site is moderately intensive (average application of N ranges from 38 to 118 kg ha\(^{-1}\) year\(^{-1}\), P application rate varied from 10 to 52 kg ha\(^{-1}\) year\(^{-1}\)), while in Vienziemīte farming activities are extensive (on average 4–5 kg N ha\(^{-1}\) year\(^{-1}\) are applied). Vienziemīte is a typical example of low input agricultural system which can be used as a reference site for water quality assessment. The description of monitoring sites and spatial scales of research are presented in Table 1. In the Bērze monitoring site, water quality is analysed at drainage field – small catchment – river scales, in the Mellupīte at the experimental plots – drainage field – small catchment scales, in Vienziemīte at drainage field – small catchment scales.

Table 1. Description of agricultural runoff monitoring sites

<table>
<thead>
<tr>
<th>Monitoring site</th>
<th>Scale of research</th>
<th>Area, ha</th>
<th>Agricultural land, %</th>
<th>Dominant soil texture</th>
<th>Water sampling procedure</th>
<th>Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mellupīte</td>
<td>Small catchment</td>
<td>960</td>
<td>69</td>
<td>Loam</td>
<td>Flow proportional</td>
<td>1995–2010</td>
</tr>
<tr>
<td></td>
<td>Drainage field</td>
<td>12</td>
<td>100</td>
<td></td>
<td>Flow proportional</td>
<td>1995–2010</td>
</tr>
<tr>
<td></td>
<td>Experimental plots</td>
<td>0.12 x 3</td>
<td>100</td>
<td></td>
<td>Flow proportional</td>
<td>1996–2010</td>
</tr>
<tr>
<td></td>
<td>Ālave River</td>
<td>9368</td>
<td>84</td>
<td>Loam, silty clay loam, clay</td>
<td>Manual</td>
<td>2005–2010</td>
</tr>
<tr>
<td></td>
<td>Small catchment</td>
<td>368</td>
<td>98</td>
<td>Silty clay loam</td>
<td>Flow proportional</td>
<td>1995–2010</td>
</tr>
<tr>
<td></td>
<td>Drainage field</td>
<td>77</td>
<td>100</td>
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<td>Flow proportional</td>
<td>1995–2010</td>
</tr>
<tr>
<td></td>
<td>Drainage field</td>
<td>67</td>
<td>100</td>
<td></td>
<td>Manual</td>
<td>1995–2010</td>
</tr>
</tbody>
</table>

The descriptive statistics and graphical representations are used to characterise data sets and create statistical information regarding the relative behaviour of the nutrient concentration data.

The Mann–Whitney U-test was used to compare means of independent data sets. The test was applied to compare nutrient concentrations between scales of measurements within one monitoring site. Significance level (p value) helps to decide whether or not the means of two data sets are equal. If p value is less than 0.05 than the difference between data sets is significant.

Results

Diffuse source pollution is strongly influenced by the hydrological processes (Wolfé, 2001), therefore, it is necessary to analyse precipitation and air temperature data measured within the study sites. During the period of the research (1995–2010), the highest mean annual precipitation has been measured in Vienziemīte (729 mm), a lower amount of precipitation has been found in Mellupīte (668 mm) and Bērze (594 mm). Comparing the precipitation in the study period with the long-term observations, it can be concluded that during the agricultural runoff monitoring period there have been medium-wet, dry and highly wet years. Thus, the analysed precipitation data is representative as it gives an insight into different moisture conditions in the study areas. In the study period, the observed air temperature data indicate that the average annual temperature is higher in the plain of Zemgale (Bērze 7.4 °C) than in the plain of Vadakste (Mellupīte 6.3 °C) and in the highland of Vidzeme (the Vienziemīte 5.6 °C). The warmest months in all the monitoring stations have been in the spring and summer seasons (May–September) when the mean air temperature is above 10 °C. However, the runoff formation process is affected not only by the meteorological conditions but also by the site specific land characteristics such as topography, soil type, and land management (Wolfé, 2001).

During the period from 1995 to 2010 in both small catchment and drainage field scales the mean annual runoff was highest in Vienziemīte comparing with Bērze and Mellupīte (Figure 2). The mean annual runoff at the Bērze and the Mellupīte drainage field scale is higher than in the small catchment, 2.85 mm and 12.70 mm, respectively, whereas in the Vienziemīte site, the higher runoff (14.07 mm) is found at the small catchment scale. The runoff in the small catchment consists of a regular drainage, surface and ground water inflow while in the drain field there is mainly infiltration water. In some cases, the drainage runoff is also supplemented by a surface runoff inflow in the tile drainage system via open inlets preventing soil erosion. This solution is used in the Mellupīte drainage field. The landscape of Vienziemīte study site is rather hilly and thus favourable for the surface runoff inflow in the stream, therefore, in the small catchment the runoff is higher than in the drain field. The landscape of Bērze monitoring site is flat, therefore, the surface runoff inflow is negligible and the runoff is similar at both monitoring scales.

The seasonal patterns of runoff influence the leaching of nutrients from the soil thus it is important to detect the periods with the highest runoff rate. During the winter period when the soil is deeper or shallower frozen it has been estimated 29–39% contribution to the annual runoff. During the spring flood period, there is formed 29–39% contribution to the annual runoff. During the spring flood period, it can be concluded that during the agricultural runoff monitoring period with the long-term observations, it can be concluded that during the agricultural runoff monitoring period
annual runoff. In contrast to the winter season when the runoff volume accumulates within a long period, in the spring the runoff occurs within a short period of time, after the spring flood peak (normally 2–3 weeks) the runoff is rapidly decreasing. The summer season is characterized by a minimum runoff, in some cases the steams during this period dry out. The autumn rain season contributes 16–25% of the annual runoff.

![Mean annual runoff at monitoring scales of the study sites (1995–2010)](image)

In general, nitrogen losses from arable land have a good correlation with water discharge from the catchment area and main losses occur with surface and drainage runoff during the high runoff periods (Iital, 2005). Monthly concentrations of nitrate nitrogen in Bērze catchment support the above-mentioned statement (Figure 3). Mean values are higher during spring flood and rainy period in the fall. Extreme values in summer can be explained by rainfall that follows dry periods.

![Minimum, mean, maximum, and outlying monthly concentrations of N-NO₃ in Bērze small catchment scale (1995–2010)](image)

Nutrient concentrations in runoff for the three monitoring sites are provided in Table 2. The results present minimum, maximum and mean values for all water samples during the monitoring period. The mean values of total N and total P concentrations clearly reflect the intensity of agricultural production within the study sites. The highest mean values of total N and total P in small catchment scale are found for the Bērze site (total N 8.57 mg l⁻¹, total P 0.169 mg l⁻¹) followed by mean concentrations of nutrients in Mellupīte (total N 3.69 mg l⁻¹, total P 0.079 mg l⁻¹) and Vienziemīte (total N 1.69 mg l⁻¹, total P 0.039 mg l⁻¹). The highest mean concentrations of total N were observed in plots and drainage fields compared with small catchments and rivers in the Bērze and Mellupīte sites, while in the Vienziemīte site variation in N concentrations between monitoring scales was negligible. The specific character of monitoring scales has to be taken into consideration when the analysis of water quality in different scales is performed. For example, runoff from the experimental plots can be considered as soil solution where the impact of retention and dilution processes is rather low.
### Table 2. Nutrient concentrations in monitoring sites

<table>
<thead>
<tr>
<th>Monitoring site</th>
<th>Number of samples</th>
<th>Total N (mg l(^{-1}))</th>
<th>Total P (mg l(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Minimum</td>
<td>Maximum</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bērze</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bērze River</td>
<td>69</td>
<td>0.80</td>
<td>8.30</td>
</tr>
<tr>
<td>Ālave River</td>
<td>69</td>
<td>0.80</td>
<td>19.90</td>
</tr>
<tr>
<td>Small catchment</td>
<td>180</td>
<td>0.13</td>
<td>29.50</td>
</tr>
<tr>
<td>Drainage field</td>
<td>162</td>
<td>0.06</td>
<td>102.70</td>
</tr>
<tr>
<td>Mellupīte</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Small catchment</td>
<td>184</td>
<td>0.53</td>
<td>16.30</td>
</tr>
<tr>
<td>Drainage field</td>
<td>154</td>
<td>1.60</td>
<td>16.80</td>
</tr>
<tr>
<td>Plots</td>
<td>72</td>
<td>2.80</td>
<td>31.67</td>
</tr>
<tr>
<td>Vienziemīte</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Small catchment</td>
<td>196</td>
<td>0.01</td>
<td>7.50</td>
</tr>
<tr>
<td>Drainage field</td>
<td>191</td>
<td>0.32</td>
<td>7.50</td>
</tr>
</tbody>
</table>

The nutrient retention processes at the monitoring scales of Bērze study site are illustrated in Figure 4 where the minimum, 25% quartile, median, 75% quartile and the maximum values of total N concentrations are presented. The extreme values were excluded from the analysed data set as they show an occasional character of the nutrient leakage.
higher than in the drainage field and 62% higher than at the catchment scale. The results of Mann-Whitney U test application shows that differences between total N concentrations within monitoring scales are significant (p=0.00). Analysing the total P concentration changes at the scales of the research, it may be concluded that the retention processes in this monitoring site are not pronounced. The nutrient concentrations observed in the drainage field are higher than in the experimental plots and the small catchment. In the drainage field of Mellupīte open inlets for surface water inflow was built in places where surface runoff is likely to accumulate. Surface water inlets can be the pathway for the direct inflow of eroded soil particles during the surface runoff events thus unlike the small catchment scale sediments are not accumulated in the water course. Accordingly, the surface water inlets significantly influence the total P concentrations in the waters of drainage system.

In the Vienziemīte, the mean concentrations of total N, unlike the Bērze and the Mellupīte, are higher at in the scale of the small catchment (1.69 mg l\(^{-1}\)), while in the drainage field (1.56 mg l\(^{-1}\)). The total N maximum concentration values both at the catchment scale and in the drainage field is 7.50 mg l\(^{-1}\). It describes that in the extensive farming conditions, the maximum total N values on both scales can be equal. The mean concentrations of total P are low and very close, in the small catchment 0.039 mg l\(^{-1}\), in the drain field 0.042 mg l\(^{-1}\). As the Vienziemīte is an example of the extensive agriculture, the nutrient concentrations of this site can be considered to be at the natural or background level.

Conclusions

During the study period the highest and lowest mean nutrient concentrations were obtained in Bērze and Vienziemīte study sites, respectively. The most important factor that influences the differences in nitrogen and phosphorus losses within catchments is application rate of mineral and organic fertilisers. Seasonal changes in N and P concentrations are caused by the weather driven fluctuation in runoff, e.g., seasonal patterns of runoff.

The analysis of nutrient concentrations obtained in different spatial scales shows that concentration of N decreases when the scale of measurements increases due to retention, dilution and transformation processes in the stream. The changes of P concentrations in waters of different monitoring scales do not show clear tendencies. Water quality concerning P concentrations is influenced by occurrence of surface runoff events in drainage field and small catchment scales and by phosphorus loading from point sources in river scale.

References


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The theme of Master thesis was “Influence of Groundwater Fluctuations on Nitrate Nitrogen Runoff in Open Channels”. Research interests: water quality modeling, groundwater monitoring in Latvia.
Correlation Between Conversion of Arable Land into Brushwood and Distance of Plots from Roads

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Abstract

This paper presents the results of a study into the correlation between the percentage of brushwood on arable land and the distance of arable land areas from the main road network. Uncontrolled conversion of arable land into brushwood usually occurs if the land is abandoned. Land abandonment is an important issue in many regions of Europe and is topical in Estonia, too. There are a number of reasons for land abandonment, and the nature of those reasons is multi-faceted. A systematic and thorough investigation into aspects and factors of land abandonment is needed to define the bigger picture of the phenomenon. The aim of this study was to test whether there was a positive correlation between the distance of arable land areas from the main road network and the percentage of brushwood on such land. The study was carried through on the basis of 15 rural municipalities in Estonia. A digital base map and orthophoto map were the main sources of data for the study. The brushwood areas on the arable land were detected through visual inspection of the orthophoto maps. Different GIS tools were used to form the necessary data base for correlation analysis, which was performed by the municipalities. The results of the study partly proved the hypothesis. A positive correlation between the distance of arable land from the roads and the percentage of brushwood area on arable land was found in six municipalities (r ≥ 0.50). It also emerged that the correlation coefficients decreased if more distant arable land area (more than 1.8 km) were included in the analysis.

Key words: land abandonment, brushwood, arable land

Introduction

Land abandonment has become more evident in recent decades in the EU (Keenleyside and Tucker 2010). Abandonment of arable land may be caused by socio-economic, ecological or political factors (Rey Benayas et al. 2007; Zaragozi, et al. 2012; Pointereau, et al. 2008; Prishchepov, et al. 2013; Silber and Wytrzens 2006; Mander and Kuuba 2004). Such abandonment in remote areas may be associated with declining subsidies, low accessibility (distance from roads, farming centres and markets), demographic factors (population density, farmer age and the labour market) and ecological aspects (parcel size, poor soil and soil depth) (Baumann et al. 2011; Gellrich and Zimmerman 2007; Pointereau, et al. 2008; Prishchepov, et al. 2013; Rey Benayas et al. 2007).

Agricultural land abandonment is a problem in Estonia also. Large-scale abandonment was evident in the country two decades ago, the major driving force behind which was socio-economic changes (Mander and Kuuba 2004). By the early 1990s around 32% of arable land had been abandoned (Peterson and Aunap 1998). A decade later this rate was much lower: approximately 10% (Keenleyside and Tucker 2010). At present, the rate of arable land abandonment is likely to be even smaller due to Estonia becoming a Member State of the European Union and obtaining the right to support from EU funds. However, the area of arable land was 620 483 hectares in Estonia in 2012, whereas in 2010 the same area was 645 067 hectares (Statistics Estonia: http://www.stat.ee/34244). This may be due to a number of reasons, for example infrastructure development, residential development, permanent grassland expansion, nature conservation, removal from production or complete abandonment.

It is necessary to know the location and extent of agricultural land abandonment in order to take the necessary action at the national or local level where needed (Keenleyside and Tucker 2010). However, land abandonment data is difficult to obtain (van Dijk, G. et al. 2004) and therefore abandonment is hard to measure and study (Keenleyside and Tucker 2010). Knowledge of abandoned agricultural land is important, because pressure from other land use types affects the future use of agricultural land (Benjamin et al. 2007).

One can assume that remote arable land areas are more likely to become covered in brushwood than areas around settlements and close to the road network. Access options wield an influence on land use conditions. It is difficult to cultivate a piece of land if access conditions are poor or there is no access at all. Remoteness and poor access conditions raise the production costs. Producers from remote areas also face disadvantages on the sales and labour markets. Thus, one can assume that if arable land is abandoned, the phenomenon is most likely to occur in remote areas.

The aim of this study was to test whether there was a positive correlation between the distance of arable land areas from the main road network and the percentage of brushwood on such land. The percentage of brushwood on arable land was used as an indicator to assess the extent of arable land abandonment. Brushwood usually appears on arable land if the area is not cultivated over a period of several consecutive years.

The results of the study showed that there is a significant correlation between the distance of arable land areas from the main road network and the percentage of brushwood on arable land in some of the municipalities studied. However, such a correlation is not found in all municipalities. Moreover, a negative correlation was detected in some municipalities.

Materials and methods

One rural municipality from each county was selected for the study. The municipalities were selected on the basis of the percentage of their arable land, which had to be as close to the average percentage of arable land in the respective county as possible. The percentage of arable land is the ratio of arable land to the total municipal area or to another region that forms a whole, e.g. a county. The schematic location of the 15 municipalities included in the study is presented in Figure 1.
The following data were used for the study:

- A digital base map of Estonia was used to determine the location of arable land areas and the state road network.
- A map of the administrative boundaries of municipalities was used to clip the arable land areas and necessary parts of the state road network from the study area.
- A map of brushwood areas on arable land was created in the process of visual inspection of orthophoto maps on the website of the Estonian Land Board (http://kaart.maaamet.ee/wms/alus). The WMS service was used for this task. Figure 2 illustrates the process and principles of creating the polygons of brushwood areas on arable land.

The next step was the generation of buffer zones around state roads. Buffer zones are needed for the determination of the distances of arable land areas from state roads and to determine the distances of digitised brushwood areas from state roads. The interval of the generated buffer zones was 100 metres. A fragment of buffer zones is presented in Picture A in Figure 3. The zone numbers were set as equal to the outer radius of the zone.

The overlay (intersection operation) of the buffer zone layer and arable land area layer split the arable land areas into smaller parts according to the boundaries of the buffer zones (see Picture B in Figure 3). Each piece of arable land obtained a zone number after this manipulation. The zone numbers described the distance of pieces of arable land from the road network, as the zone numbers were set as equal to the outside radius of the buffer zones. Similar manipulations were also performed with the digitised brushwood areas (see Picture C in Figure 3).

Figure 1. Location of municipalities studied (study area)

Figure 2. Example of brushwood determination process on arable land. The dotted white line (Picture B) is the digitalised polygon of brushwood on the arable land. There is no brushwood on the arable land according to the base map (Picture A).

Figure 3. Example of buffer zones around road (Picture A), overlay of arable land with buffer zones (Picture B) and overlay of arable land and digitised polygons of brushwood areas on arable land (dark grey, Picture C)
The final task in the formation of the data set for correlation analysis was the calculation of the percentage of brushwood areas on arable land. For this purpose the areas of arable land by zone and areas of brushwood by zone were calculated. The quotient of these two groups of figures is the percentage of brushwood areas on arable land by zone. Finally, the correlation between the zone numbers and the percentage of brushwood areas on arable land was calculated. The correlation coefficients were calculated by the municipalities for the entire set of data.

Results

In order to better understand the results of the study, the main characteristics of the municipalities studied need to be identified. Table 1 presents the general picture of the percentage of arable land in land stock and the percentage of brushwood areas on arable land in the municipalities. Data regarding the density of the main (state) road network and the density of population are also presented.

Table 1. **Main characteristics of municipalities studied**

<table>
<thead>
<tr>
<th>Municipality</th>
<th>Municipality area (ha)</th>
<th>Arable land area (ha)</th>
<th>Percentage of arable land in municipality</th>
<th>Area of brushwood on arable land (ha)</th>
<th>Percentage of arable land area covered with brushwood</th>
<th>Density of road network (km per sq. km)</th>
<th>Density of population (inhabitants per sq. km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abja</td>
<td>29018</td>
<td>8641</td>
<td>29.78</td>
<td>569</td>
<td>6.58</td>
<td>0.352</td>
<td>7.25</td>
</tr>
<tr>
<td>Jõgeva</td>
<td>45888</td>
<td>14101</td>
<td>30.73</td>
<td>292</td>
<td>2.07</td>
<td>0.360</td>
<td>9.40</td>
</tr>
<tr>
<td>Jõhvi</td>
<td>12394</td>
<td>2880</td>
<td>23.24</td>
<td>58</td>
<td>2.01</td>
<td>0.403</td>
<td>102.78</td>
</tr>
<tr>
<td>Kanepi</td>
<td>23147</td>
<td>7120</td>
<td>30.76</td>
<td>492</td>
<td>6.90</td>
<td>0.685</td>
<td>9.84</td>
</tr>
<tr>
<td>Kernu</td>
<td>17485</td>
<td>4137</td>
<td>23.66</td>
<td>54</td>
<td>1.29</td>
<td>0.361</td>
<td>13.75</td>
</tr>
<tr>
<td>Kohila</td>
<td>23012</td>
<td>6317</td>
<td>27.45</td>
<td>363</td>
<td>5.75</td>
<td>0.356</td>
<td>31.86</td>
</tr>
<tr>
<td>Koonga</td>
<td>43966</td>
<td>7949</td>
<td>18.08</td>
<td>124</td>
<td>1.56</td>
<td>0.219</td>
<td>2.28</td>
</tr>
<tr>
<td>Käina</td>
<td>18914</td>
<td>4946</td>
<td>26.15</td>
<td>91</td>
<td>1.84</td>
<td>0.555</td>
<td>9.71</td>
</tr>
<tr>
<td>Martna</td>
<td>27046</td>
<td>5938</td>
<td>21.96</td>
<td>14</td>
<td>0.23</td>
<td>0.306</td>
<td>2.95</td>
</tr>
<tr>
<td>Muhu</td>
<td>20889</td>
<td>4848</td>
<td>23.21</td>
<td>198</td>
<td>4.09</td>
<td>0.393</td>
<td>7.10</td>
</tr>
<tr>
<td>Puka</td>
<td>20083</td>
<td>5258</td>
<td>26.18</td>
<td>428</td>
<td>8.14</td>
<td>0.588</td>
<td>7.60</td>
</tr>
<tr>
<td>Rannu</td>
<td>15745</td>
<td>6266</td>
<td>39.80</td>
<td>30</td>
<td>0.48</td>
<td>0.315</td>
<td>9.56</td>
</tr>
<tr>
<td>Türi</td>
<td>59829</td>
<td>21020</td>
<td>35.13</td>
<td>275</td>
<td>1.31</td>
<td>0.355</td>
<td>15.74</td>
</tr>
<tr>
<td>Võru</td>
<td>20144</td>
<td>5822</td>
<td>28.90</td>
<td>397</td>
<td>6.82</td>
<td>0.614</td>
<td>24.53</td>
</tr>
<tr>
<td>Väike-Maarja</td>
<td>45780</td>
<td>16383</td>
<td>35.79</td>
<td>140</td>
<td>0.85</td>
<td>0.256</td>
<td>9.73</td>
</tr>
</tbody>
</table>

One can see from Table 1 that there are significant differences between the municipalities studied. The total area of the municipalities differs almost five-fold. The smallest municipality is Jõhvi (12 394 ha) and the largest is Türi (59 829 ha). The difference in the arable land areas in these municipalities is even greater. The areas of the smallest and largest municipalities are 2880 ha (Jõhvi) and 21 020 ha (Türi) respectively.

The percentage of brushwood on arable land varies among the municipalities remarkably. While the percentage of brushwood on arable land is 0.23 and 0.48 percent in Martna and Rannu municipalities, respectively, in Puka and Kanepi municipalities these figures are 8.14 and 6.90. The density of the state road network and population densities varied in the study area, too. Taken together, the data in Table 1 show that the land use conditions in these municipalities are very different.

Table 2 presents the main results of the study. The correlation coefficients were calculated for different distances of arable land from the road network. The shortest distance was 1.5 km and the number of zones was respectively 15. One zone (width: 0.1 km) was added and the correlation coefficients were calculated again. Such an increase in distances was repeated up to 2.5 km. After this the distance was increased by 0.5 km. Thus, in the case of a distance of 1.5 km the number of observations (N) is 15. Not all of the calculated correlation coefficients are presented in Table 2. The reason for this is that the correlation coefficients do not change rapidly if the distance is increased by 0.1 km. Thus, inclusion of all of the coefficients would not add extra information. It was not possible to calculate the correlation coefficients for all zones for some municipalities because of missing areas that were beyond a certain distance from the road. For example, arable land in Jõgeva only extends 2.3 km from the road network. Such cases are marked in Table 2 as ’NA’ – not available for calculation of the correlation coefficients.
Table 2. Correlation between distances of arable land from roads and ratio of brushwood on arable land by maximum distance from roads

<table>
<thead>
<tr>
<th>Municipality</th>
<th>Maximum distance of arable land areas from roads as used for calculations of correlation coefficients (km)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>up to 1.5</td>
</tr>
<tr>
<td>Abja</td>
<td></td>
</tr>
<tr>
<td>Jõgeva</td>
<td>0.44</td>
</tr>
<tr>
<td>Jõhvi</td>
<td>-0.18</td>
</tr>
<tr>
<td>Kanepi</td>
<td>0.66*</td>
</tr>
<tr>
<td>Kermu</td>
<td>0.17</td>
</tr>
<tr>
<td>Kohila</td>
<td>-0.30</td>
</tr>
<tr>
<td>Koonga</td>
<td>-0.49</td>
</tr>
<tr>
<td>Käina</td>
<td>-0.56*</td>
</tr>
<tr>
<td>Martna</td>
<td>-0.15</td>
</tr>
<tr>
<td>Muhu</td>
<td>-0.50*</td>
</tr>
<tr>
<td>Puka</td>
<td>0.66*</td>
</tr>
<tr>
<td>Rannu</td>
<td>-0.10</td>
</tr>
<tr>
<td>Türi</td>
<td>0.23</td>
</tr>
<tr>
<td>Võru</td>
<td>0.63*</td>
</tr>
<tr>
<td>Vääke-Maarja</td>
<td>0.47</td>
</tr>
<tr>
<td>All municipalities</td>
<td>0.11</td>
</tr>
</tbody>
</table>

* - correlation coefficients are significant at a confidence level of 95% (α > 0.05)
NA – not available because of the lack of arable land in particular zones

A significant positive correlation between the distance of arable land areas from the road network and the percentage of brushwood on the arable land was found in the first group of municipalities: Abja, Jõgeva, Kanepi, Puka, Võru and Vääke-Maarja. However, a better correlation is observed if the distance from roads is less than 2.0 km. This second group consists of municipalities where there is a negative correlation between the distance of arable land areas from the road network and the percentage of brushwood on the arable land: Koonga, Käina and Muhu. A stable negative correlation was found in Koonga municipality. However, in Käina municipality the negative correlation was significant when the distance from the roads to the arable land areas was up to 1.5 km. For Muhu municipality this limit was 1.8 km.

The third group consists of municipalities where there was no significant correlation between the distance of arable land areas from the road network and the percentage of brushwood: Kernu, Kohila, Martna, Rannu and Türi. There is no significant correlation if the calculations for the entire set of data are performed (see the last row in Table 2).

It is important to analyse the charts of the changes in the percentage of brushwood on arable land depending on the distance of such land from the road network. Such analysis supports a better understanding of the process of how the percentage of brushwood on arable land changes depending on the distance from the road network. Figure 4 presents four examples of such changes.

Graph A in Figure 4 depicts a case where the percentage of brushwood on arable land increases if the distance from the road network increases; the correlation is significant. Graph B depicts a case where there is a positive but not significant correlation. The feature specific to these two examples is that the trend of changes in the percentage of brushwood on arable land is relatively stable if the distance of the land from the roads is less than two km. The trend is more varied if the distance is more than two km.

Graph C depicts a case where the percentage of brushwood on arable land decreases as the distance from the road network increases; the correlation is significant if all zones (at a distance of up to 3.5 km) are included. One can see a certain stability in the trend if the distance of the arable land from the roads is less than 1.5 km. Graph D depicts a situation where the variability of the trend is quite similar for all distances of arable land from the road network. The correlation is significant in this case. It is necessary to add here that the y-axes in the different pictures in Figure 4 have different scales. This should be kept in mind if the different pictures are compared.
Discussion

Brushwood on arable land was detected in all of the municipalities studied, but the percentage varies remarkably from one municipality to the next. Whereas in Martna municipality the percentage of brushwood on arable land was just 0.23 percent, in Kanepi municipality the same figure was 6.90 percent: 30 times higher. This means that the extent of land abandonment in municipalities is different. At the same time, a clear positive correlation between the distance of arable land from the road network and the percentage of brushwood on arable land was identified in six municipalities.

A possible explanation for the lack of a significant correlation between brushwood on arable land and distance from the road network in some municipalities is associated with various characteristics: population density, the location of arable land in relation to roads, the density of the road network and the economic conditions of the municipalities. The percentage of arable land area that is covered with brushwood is very low in Martna and Rannu municipalities (respectively 0.23 and 0.48 percent). It is difficult to find a correlation between two variables if one of them is close to zero. A low percentage of arable land area that is covered with brushwood is also found in Kernu, Käina and Türi municipalities. Population density is also relatively high in Kernu, Türi and Kohila municipalities.

There is an obvious negative correlation between the distance of arable land from the road network and the percentage of brushwood on arable land in Koonga and Muhu municipalities. The percentage of arable land is low in both municipalities. Moreover, population and road network density are low in Koonga municipality. Two specific features of Jõhvi municipality should be noted: a) it is situated in the industrial region of Estonia, including mining areas; and b) the high density of the population (see Table 1). The result of these factors is a negative correlation between the distance of arable land from the road network and the percentage of brushwood on arable land if the distance from the roads is less than three kilometres; see also Picture C in Figure 4.

Data collection by visual examination of orthophoto maps was very time-consuming in this study. Such a method of data collection can be used for small areas. The accuracy of the collected data depends on the quality of the orthophotos and the skills and knowledge of the digitiser. The time at which the aerophotos were taken also has an impact on the quality of the orthophoto maps. It is not easy to recognise broadleaf brushwood if the photos were taken in spring before the leaves appear on the trees. Studying the extent of brushwood on arable land should be faster and more accurate in order to obtain more complete and reliable data. The implementation of Lidar technology for the detection of brushwood on arable land seems to be a promising option for the development of methodology in these kinds of studies.

This study examines the conversion of arable land into brushwood during the last four to five years. The brushwood was detected if there was a difference between the topographic map and the orthophoto map (see the example in Figure 2). Some former arable land areas are already marked on the current topographic map as brushwood or even forest areas. A 15- or 20-year-old digital map in a usable vector format with arable land areas is not currently available. The rate of conversion of the arable land into brushwood during the last 20 years is probably higher than was detected in this study. Comparison of the present arable land areas and these areas in the early 1990s would be the second task in order to gain more complete information about the extent of conversion of arable land into brushwood.

Such conversion exists and varies in all 15 municipalities. Brushwood on arable land is a clear indicator of agricultural land abandonment. Knowledge about the status and changes of agricultural land use is needed for better
farming and to ensure biodiversity and ecosystem stability. Agricultural land use forms part of rural development and has aesthetic value from the point of view of the rural landscape. Therefore it is important to monitor agricultural land abandonment, as being aware of abandonment determinants can be useful in order to take economic, political, environmental and other necessary measures to achieve better use of land as a limited resource. This study forms preliminary research in the field in the Estonian context and there is need for further research to increase data accuracy and expand the study area.

Conclusions

This study has shown that a significant positive correlation (r ≥ +0.5) between the distance of arable land from the road network and the percentage of brushwood on arable land existed in six of the municipalities studied. At the same time, in one municipality a significant negative correlation was observed. The correlation between the distance of arable land from the road network and the percentage of brushwood on arable land was not significant in several municipalities. This is a sign that land abandonment in the form of conversion of the arable land into brushwood is a complicated phenomenon.

Also, it emerged that the correlation between the distance of arable land from the road network and the percentage of brushwood on arable land is better closer to the road zones. The correlation coefficients decreased when the arable land areas that are more distant (more than 1.8 kilometres) from roads were included in the analysis.

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Global Warming and Extreme Meteorological Phenomena Recorded in the First 12 Years of the 21st Century in Romania

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Abstract

This article presents the results regarding the weather evolution over the last 52 years, in a region from South-Eastern Transilvania (Romania). It was found that the first decade of the 21st century was the warmest in the entire period taken into study (52 years). Statistical indicators were calculated using the chronological series of meteorological daily data which was recorded for the mentioned period at two weather stations within the studied region (Ghimbav, Brașov etc). If compared with the statistical indicators of the entire time frame, the highest annual mean temperature (i.e. 9°C) was recorded in 2007 being closely followed by that of the year 2012 (8.9°C). The general regression model developed for the mean annual temperature presented an ascending trend for the studied period, fact which was confirmed also in case of the mean temperatures for July and January. The values of all the other parameters related to the thermal and rainfall regime revealed an increment tendency. The mentioned thermal modifications had several consequences in the weather state during the studied period: increased frequencies and intensities of frosts and blizzards, excessive rain episodes (which generated catastrophic floods) contrasted by dry periods. The results of this study may be very useful in understanding the climate change as well as for the scientific foundation of agricultural and forest related management and policies, in the future.

Key words: climate changes, extreme meteorological phenomena, weather evolution trend.

Introduction

Climate changes have already proved themselves to have significant effects on the agricultural crops, water (Falloun and Betts, 2010) and forest ecosystems (Allen et al. 2010), threatening the food, water and energy supply (Li and Shu, 2013) as well as other important supply chains of the mankind. Many studies have been done in what concerns the interaction between the climate change and agriculture. While some recent of them emphasized the translation of suitability for agricultural crops to the northern parts of Europe (Falloun and Betts, 2010) or assessed the climate change impact (Molua, 2009, Rivington et al., 2013), other focused on the adaptive measures for agriculture (Mestre-Sanchis and Feijoo-Bello, 2009, Reidasma et al., 2010, Vermeulen et al., 2012, Li and Shu, 2013, Rivington et al. 2013). Being ones of the widest ecosystems on Earth, forests were addressed also in studies related to climate change, and some studies revealed that they will be (Johnston and Hessel, 2012) or are already affected (Allen et al., 2010) by climate change. That represented a sufficient reason for investigating the forest dynamics under climate change (Liang et al., 2011) as well as for thinking in direction of forestry and forest adaptation to climate change (Schoene and Bernier, 2012).

According to the climate data summary report realized by Organisation Météorologique Mondiale (OMM) in 2013, the first decade of the 21st century was the warmest period since the meteorological measurements were first introduced. The annual amount of precipitation was also higher than the multiannual mean, especially in 2010. The intensity and frequency of extreme meteorological phenomena were also increased, examples of this being represented by the heat waves that hit Europe in 2003 and 2010, catastrophic floods from Pakistan in 2010, Katrina hurricane in USA during 2005, as well as the extended periods of drought in Amazon basin and other regions. One of the greatest challenges that scientists are currently facing is to determine the roles attributed to the natural variability of the climate and climatic changes, of human origin, respectively, in the current evolution of the climate.

Nevertheless, these phenomena should be first acknowledged before being explained and forecasted in order to prevent or diminish their devastating effects. In Romania, the first decade of this century was marked by severe meteorological events that continued also in the first three years of the second decade, leading to severe effects: hot periods contrasting with frosty hibernal episodes, increasing violent blizzards, excessively rainy periods accompanied by dangerous phenomena of atmospheric instability (thunderstorms), as well as disastrous floods followed by prolonged periods of droughts having severe consequences for agriculture and other economic and social sectors. Likewise, in Brașov region, located in the South-Eastern Transylvania, this period was the warmest and the wettest in the studied history of local meteorology. The year 2007 was the warmest year here as well, with increased hygrothermal discomfort.

Our analyses were based on daily visual and instrumental meteorological data from several meteorological stations belonging to the Regional Meteorological Centre South Transilvania-Sibiu, as well as on data obtained through internet information flows, press release in the field of study and special literature. We used the reference weather station Brașov-Ghimbav, located in the depression plains of the largest intermountain depression in the whole Carpathians range, at an altitude of 534m, in order to collect the daily weather data recorded throughout the last 52 years, as well as weather station Brașov-city (609m), in order to collect chronological series of data across 96 years (1912-2007). The meteorological data were processed in accordance with the analytical methods of the mathematical statistics, generally accepted and used in climatology (Arlery, R. et all., 1973).

We believe that the reference meteorological station Brașov-Ghimbav, having the geographic coordinates 45°42'N , 25°32'E and an altitude of 534 m has a representative geographical position for Brașov area and for the vast geographical area named Transilvania, which is located in the centre of Romania, in the midst of the Carpathians Mountains (Figure 1).
The dynamic factors (general circulation of the atmosphere) together with the physical-geographical factors (Carpathians, the Black Sea and the Danube) divide the regional climate zones of Romania into sub-regional divisions (climate sectors and sub-sectors):

- a moderate continental climate sector, in the West and Center of the country;
- a continental climate sector in the strict sense, more arid, in the East, South-East and South of the country;
- a Carpathian climate sector - overlapped horizontally on the Carpathian mountain landforms.

Setting these sectors and sub-sectors as background, the Carpathian amphitheatre, arranged in concentric steps to the plains of the Danube, Tisa and to the Moldavian Plateau, shapes the altitudinal climatic belts, as well as the fragmentation into a variety of local climates, orographically conditioned – topoclimates (Marcu M., 1993).

Research results

The warmest decade

Our research concerning the climatic evolution over the latest period made use of several parameter values for the thermal regime, which makes the subject of our subsequent analysis. It is well known that the mean annual temperature is the most representative parameter for the thermal regime and, at a larger scale, for the climate of a particular region.

The values of the mean temperatures recorded at the reference meteorological station – Ghimbav (Figure 2), showed that the first decade of the 21st century was the warmest in the considered reference period. The average temperature was higher than in the 1971-1980 decade by 0.7°. Also, the statistical analysis indicated that five of the ten years in the studied decade registered a mean annual temperature higher than 8.5°C. These indicators were also observed in case of years 1999 and 2000 respectively, which preceded the studied decade.

The increment of mean annual temperatures by 0.3 - 0.4°C from one decade to another over the last 30 years was more significant than the increase between two sequent decades from the beginning of the 20th century. This aspect emphasized that the warming process has been deepened in the latest period. The data collected from the reference weather station also revealed that the highest mean temperature (9.0°C) was recorded in the year 2007, followed by the
year 2012, when a mean temperature of 8.9°C was recorded. The same ascending trend of the mean annual and monthly temperatures (January) is demonstrated by the linear regression models presented in Figures 3-4.

![Image](https://via.placeholder.com/150)

**Figure 3.** Evolution of yearly average temperature in the period 1961-2012 at Ghimbav

![Image](https://via.placeholder.com/150)

**Figure 4.** Evolution of the monthly average temperatures in January during 1961-2012

The sum of mean positive daily temperatures (> 0°C) represents a climatic parameter of great importance in the large-scale ecology, phenology and biology.

The sum of positive temperatures considered together with the annual duration of such temperatures represent an important indicator of the calorific potential of a particular climate (Marcu, V., 2001). In Romania, the highest sum of mean daily temperatures (over 4000°C) was registered in Eastern Dobrogea and the extreme South.

By cumulatively summing the mean of positive daily temperatures for each year, we found that Brașov area has an annual average thermal potential of 3185.3°C (Figure 5), ranging from 3022.0°C in the coldest year (1985) and 3768.1°C in the warmest year (2012). Considering this criterion, the year 2007 (3561.6°C) and the year 2010 (3551.7°C) were very warm years as well. The data also revealed that out of the 52 years analysed, only five years cumulated means of positive daily temperatures higher than 3500°C and all these years belong to the latest decade (2001-2010).

![Image](https://via.placeholder.com/150)

**Figure 5.** Sum of the average daily temperature greater than 0°C. Average on 50 years and individual sums of the extreme years: the warmest (2007, 2012) and the coldest (1985)

**Daily maximum and minimum temperatures** indicate the real limits within which the daily oscillations occurred (the contrast between day and night). The mean monthly and annual values represent an indicator of the heating and cooling capacity of a regional climate on a period of time. Therefore, the mean of daily maximum temperatures in the warmest month of the year (July) for the entire period submitted to analysis had a value of 25.1°C,
January 0.5°C and annual value 14.1°C. On decades (Figure 6), the mean temperature of July has registered increasing values, from 23.6°C in the 1971-1980 decade to the highest recorded values in the 2001-2010 decade (26.9°C). There should be mentioned that, by comparison with the mean temperature of July throughout the analysed period - 52 years (25.1°C), from the last 12 years (2001-2012), eleven registered higher value, while three years (i.e. 2012, 2007 and 2003) registered a mean value ranging from 29.3°C (2007) to 31.3°C (2012), being higher by 4.2 - 6.2°C than the average of the respective decade. Another convincing example of the increasing frequency and intensity of meteorological phenomena in recent years is the growing number of hot days with maximum temperature ≥30 °C named tropical days in climatology. Since 2000, more and more years have registered more than 15 tropical days: 2000 (18 days), 2007 (23 days), 2010 (20 days), culminating in 2012 (50 tropical days).

Figure 6. Average of the maximum daily temperature, in July, on decades

In addition, over the last decade, from one year to another, the number and duration of hot episodes with maximum temperature > 35°C increased, reaching values of up to 40-42°C in the Danube Plane, in the extreme South of Romania, getting as close as to the absolute maximum temperature of our country (44.5°C) recorded on the 10th of August, 1950.

Contrasting summer heat waves, frosty hibernal episodes and strong blizzards

The Summary Report published by OMM (2013) regarding the decade of climate extremes showed that the northern hemisphere experienced extreme hibernal conditions during December 2009 and February 2010 concretised in prolonged cold waves and snowfalls, which made more than 450 victims all across the Europe. Similarly, in the recent years, Romania has been the occurrence place of numerous phenomena which are rather characteristic to severe winters: frosty episodes preceded by blizzards in winters (2009-2010, 2011-2012). There should be mentioned also the extra-season blizzard which occurred in late of March 2013. The 2009-2010 winter was considered, in all the Europe, an unusually cold winter (Andrei S., 2011). For instance, in Romania, it brought in mind the frosts which occurred during the winter of 1941-1942. In total, 15 meteorological events of severe winter occurred during the period 12th December 2009 - 23rd February 2010. The highest degree of severity was recorded during the blizzard that took place between 6th and 9th February 2010, lasting for 54 hours and affecting half of the country (road traffic, schools activities in Bucharest and another 13 counties); the shore of the Black Sea was frozen and 44 people died (until the 27th of February, 2010) because of the cold (Marcu V., 2012).

Figure 7. These extreme phenomena have been produced in conditions of strong thermo-baric contrast between the north-east European anticyclone’s dorsal and the very deep depression from the eastern Mediterranean basin (http://www.wetter3.de)
The episodes of blizzards and frost from winter of 2011-2012 (26\textsuperscript{th} January - 20\textsuperscript{th} February) generated a severe winter with exceptional events, almost at the same intensity like the blizzard from February 1954. During the episodes of snow and frost from winter of 2011-2012, the snow blown by the wind at speeds reaching 70 km h\textsuperscript{-1} led to the formation of snow drifts higher than the roofs of the houses in the village outskirts exposed to the Ice North Wind. During the same events, the Danube froze and the shore of the Black Sea also froze across a width of 300m (Figure 7). Correspondingly, in Braşov, the mean recorded temperature in February 2012, was by 3.5°C lower than the multiannual mean for this month (-6.1°C as compared to -2.6°C). Therefore, the main spring indicator species blossomed only in the 26\textsuperscript{th} of March that year, this being an anomaly when considering their usual blossoming date – around 1\textsuperscript{st} of March (snowdrop - Galanthus nivalis and mezereon Daphne mezereum).

The above mentioned exceptional phenomena (typical to severe winters), as well as others, such as the extra-season blizzard which took place at the end of March 2013, occurred under the synoptic conditions of the atmospheric blocking pattern, imposed by the North-Eastern European anticyclonic ridge and expressed through the coupling between the anticyclonic ridge and cyclonic formations in the Mediterranean basin.

Rains, floods and drought

The recently published data by OMM showed that the mean annual continental precipitation from the warmest decade (2001-2010) has been superior to the normal values calculated for the period 1961-1990. “The climatic changes are very likely to have an impact upon the frequency and intensity of extreme precipitation episodes” (OMM, 2013) The rainfall data recorded in Brașov enabled us to make similar observations: the mean annual rainfall in the 2001-2010 decade was higher than the mean of the 1961-2012 (647.1 as compared to 600.4 mm). In this warm decade the amount of precipitation was at the same time larger than that of all decades of the period submitted to analysis (1961-2010) and record-breaking annual amounts of precipitation were recorded (887.4 mm in 2005 and 861.6 mm in 2010). This decade also revealed six years with larger amounts of precipitation than the mean of the period 1961-2010 as well as three years with defective precipitation (2002, 2003, 2004). Also, in two close years to this rainy decade, very low mean annual rainfalls were recorded (383.4 mm in 2000 and 490.4 mm in 2011 respectively). This aspect, which reflects the great inter-annual variability of precipitation in the studied area, was also emphasized by some examples illustrating the striking contrast between some episodes of excessive rain and episodes of drought that succeed even during the same summer season, such as: (prolonged) period of atmospheric instability between 1\textsuperscript{st} May and 8\textsuperscript{th} September 2009 which was characterised by spectacular alternations between rainy episodes (with high-intensity thunderstorms, violent storms - the 2\textsuperscript{nd} of June, 2009) and hot episodes - anticyclonic type and droughts. The rainy period was clearly delimited by periods with very deficitary precipitation. Excessively rainy period with catastrophic floods in the summer of 2010 began by a heavy convectional rainfall in the night of 15\textsuperscript{th} /16\textsuperscript{th} June 2010 and continued with 6 major rainy episodes, culminating with the one recorded on the 28\textsuperscript{th} -29\textsuperscript{th} June 2010 (Timu M.D., 2011). Successive torrential rainfalls, generating large amounts of water, caused catastrophic flooding in 27 counties from Transilvania and Northern Moldova. The rain covered all the country and the catastrophic floods caused most of the damage and casualties in Northern Moldova. During the night of 28\textsuperscript{nd}/29\textsuperscript{th} June and during the day of 29\textsuperscript{th} June 2010, the amount of precipitation exceeded by 2-3 times the climatology-related norms. In just 10 days (during the last decade of June 2010) rainfall exceeded 200 mm, representing twice of the typical rainfall in two months (June and July). However, the danger consisted of the fact that these huge amounts of water fell in just a few hours. On the 6\textsuperscript{th} of July, 2010, the Danube water level increased and became a threat to the Danube’s dams located at Fetești, Brăila and Galați. In Călărași, Borcea (a branch of the Danube) flooded 12,000 hectares of agricultural land.

The origin of these extreme meteorological phenomena was a double structure of “atmospheric blocking” (anticyclonic type: one in Western Europe, covering the North-Eastern basin of the North Atlantic and another, much higher above the Russian Plain, where it remained for more than 2 months, causing torrential rains and floods in the Central-South-Eastern Europe and heat and severe drought in the Russian Plain (Huștiu, M., 2011).

Under similar conditions, related to an Eastern European anticyclonic blocking, two episodes of heavy rains and floods emerged during the period 25\textsuperscript{th} June - 6\textsuperscript{th} July 2011: the cyclone of Mediterranean origin, which arrived in the Black Sea, was blocked by the Eastern European anticyclonic ridge and gained a retrograde motion, generating torrential rains and strong thunderstorm phenomena in the studied region. Excessive, torrential rainfall in the warm semesters of 2009 and 2010, contrasted sharply with rainfall deficit in the second semester of 2011 (when the autumn agricultural processes faced difficulties) as well as with the dry period of June-August 2012 when, under the conditions of excessive thermal regime and deep rainfall deficit, maize and sunflower crops were seriously compromised in almost all agricultural areas of the country, leading to a substantial reduction in budget revenue (about 20%). Herbaceous vegetation dried and an increasing number of dry trees were recorded in forests.

Conclusions

In the recent years, due to global warming, numerous exceptional phenomena occurred in the area taken into study, namely “extreme phenomena” according to the current terminology, or, in a broader sense, “climate changes”.

The analysed data regarding the main characteristics of the thermal regime revealed that the first decade of the 21\textsuperscript{st} century (2001-2010) was the warmest in the entire period submitted to study. The highest mean, i.e. 9°C, was recorded in 2007, being 1.3°C higher than the mean temperature for the studied period, followed by a mean temperature
of 8.9°C, recorded in 2012. The developed regression models indicated an ascending trend of the mean annual temperature, as well as of the mean temperature of the months of July and January. The values of all the other parameters of the thermal regime as well as those mentioned for the extreme events, revealed an increment tendency in what concerned the thermal contrasts and the violence of meteorological phenomena. In contrast to summer heat waves, the frequency and intensity of frosty hibernal episodes and blizzards increased.

We have found that the precipitation trend was descending, fact which was similar to other regions of Romania. Yet, it appeared as being obvious the inter-annual variability of precipitation as well as the contrasts between episodes of excessive rains, facts which led to catastrophic floods.

The choice of the weather station Brașov-Ghimbav (534 m) as reference station was in accordance with the aim of our research. Due to its geographical position and to the meteorological data provided, this weather station proved its representativeness for the complexity of atmospheric processes shaping the weather and climate in this area, located within the boundaries of the great curvature of Carpathians. This might be sustained by the similarities found between the data provided by OMM and those provided by the chosen station: the 2001-2010 decade was the warmest decade, at the global scale, a decade of climatic contrasts, and the year 2007 was the warmest year in almost all Europe.

Between 2001 and 2010 many countries were hit at one time or another by heat waves. The year 2010 was the wettest year ever recorded worldwide. It was the year of great floods, both, in Romania and other European countries. In 2012, while the Arctic ice was diminishing its surface to a minimum record, in July, Brașov-Ghimbav weather station recorded the highest mean temperature in the history of Brașov meteorology (almost 28°C, by 5 degrees higher than the mean of 52 years, breaking the record of 24° registered in 2007).

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Ground Vegetation Development after Surface Fire in Scots Pine Forests

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Abstract

The influence of low-intensity surface fires on the development of ground vegetation in Scots pine (Pinus sylvestris) stands on sandy soils (Arenosols) was studied. The study was conducted in eastern part of Lithuania (55°35'N, 26°07'E) in 60-year-old pure Scots pine stands. The surface fire occurred at the end of April 2006. In total 4 permanent transects (20x1 m) with 20 sampling plots (1x1 m) were established for the ground vegetation study in burned site and untouched not-burned site (control). Vegetation was recorded annually in June-July 2006-2011. Surface fire has destroyed above-ground part of ground vegetation. Ground vegetation began to recover in the subsequent years. 3-4 years after the fires the burned sites had even higher number of species and ground vegetation coverage than in unburned sites. The pioneer herb species and dwarf shrubs (Vaccinium myrtillus) spread out. The recovery of moss layer was much slower. The common forest species were still absent in burned area 5 years after fire.

Keywords: plants, species, surface forest fire, Pinus sylvestris.

Introduction

Disturbances change the spatial structure of forested landscape, increase the amount of edges and initiate changes in the abiotic and biotic environment (Haila, 1999; Brazaitis et al., 2005, Marozas et al., 2005, 2009). Forest fire is an important ecological factor affecting vegetation composition, energy fluxes and biogeochemical processes in boreal forest zone (Parviainen, 1996; Angelstam, 1998; Bergeron et al., 2002; Kuuluvainen, 2002; Ryan, 2002; Wallenius et al., 2007). Forest management should consider the impact of fire as the increase of forest fires are expected to occur in future as a consequence of global climate changes (Päättalo, 1998; IPCC, 2007; Flannigan et al., 2009).

The effect of the fires on forest depends on fire severity and duration. Severe crown fires can destroy forest totally, and alter vegetation composition, soil physical, chemical and microbial processes (Ice et al., 2004; Certini, 2005). Surface fire mainly affect the species composition of ground vegetation, tree regeneration conditions and in short-time increase of plant available nutrients in soil (Parviainen, 1996; Granström, 2001; Gromtsev, 2002; Ryoma and Laaka-Lindberg, 2005; Jayen et al., 2006; Marozas et al., 2007; Parro et al., 2009; Marozas et al., 2013).

Some studies on impact of surface fire to vegetation in pine forest were done in European hemiboreal forest zone (Zackrisson, 1977; Marozas et al., 2007; Parro et al., 2009). Moreover, there is a lack of more investigations on vegetation dynamic after forest fire.

In Lithuania the annual number of forest fires is about 700 (from 200 to 1600 per year) (LME/SFSS, 2013). Total burned forest area is from 100 to 700 ha annually. Average burned area per one fire is 0.45 ha. More than 84 % of fires emerge in Scots pine forests. The most common are surface fires (97.3 %). Crown and underground fires consist only to 1% and 1.7 %, respectively.

The aim of this study was to determine the recovery of ground vegetation, in Scots pine forests after the low-intensity surface fire.

Materials and Methods

The study area was located in eastern part of Lithuania (Zarasai district) (55°35' N, 26°07' E) and it falls in the hemiboreal forest zone of Europe (Ahti et al., 1968). The height above sea level is about 150-180 meters. The mean annual temperature ranges from +5.4 to +5.8 °C. Annual mean precipitation is between 600 and 700 mm (Bukantis, 1994). Sandy soils and pure Scots pine (Pinus sylvestris) stands prevail in the study area.

The study was carried out in 60-year-old pure Scots pine stands with the undergrowth of Norway spruce (Picea abies). All studied stands were growing on nutrient-poor sandy Arenosols. In these stands surface fire occurred at the end of April 2006. Scots pine trees were not damaged. Meanwhile Norway spruce undergrowth and shrubs were killed totally and ground vegetation cover had burned. The area of fire was about 60 ha.

In total 4 permanent transects (20x1 m) with 20 sampling plots (1x1 m) were established for the ground vegetation study in burned site and untouched not-burned site (control) of Scots pine stand. Vegetation was recorded annually in June-July 2006-2011. In transects all species (species names according to Jankevičienė, 1998) and its projection cover (%) were recorded each year.

Because vegetation data were not normally distributed, we used nonparametric Mann-Whitney test to distinguish differences in species number, vegetation projection cover between burned and untouched control sites. The nonparametric Wilcoxon test was used to test differences among pairs of data set in different years. Statistical analyses were conducted using the software STATISTICA 8.0.

Results and discussions

In total 28 different species were found during 6 years period in herb and moss vegetation of burned and control sites of Scots pine stands. Average species number per 1 m² significantly (p<0.05) decreased in the first year after the surface fire (Fig. 1). In the subsequent years species number slightly increased, and in the fourth year after surface fire it...
was even higher than that in non-burned control site of pine stand. Following two years the species number did not changed. That species number increase was contributed mainly by spread out of pioneer early successional herb species (Calamagrostis epigejos, Equisetum hyemale, Pteridium aquilinum, Rubus idaeus, R. saxatilis, Scorzonera humilis, Solidago virgaurea, Ceratodon purpureus, Polytrichum juniperinum). Other studies showed the same decline in the number of species immediately after the fire and the following increase after a few years (Nuzzo, 1996; Parro et al., 2009).

The reduction of herbaceous and dwarf shrub coverage due to surface fire was observed only during the first year. Projection cover recovered in the second year after the surface fire. In third year projection cover of herbaceous and dwarf shrub species was even higher than that in the control site (Fig. 2). Following years projection cover did not changed significantly. Such increase was mainly because of Vaccinium myrtillus (near 50%) coverage in burned areas.
Herbaceous, moss and dwarf species prevailed in ground vegetation of Scots pine stand (Table 1). Only 2 species of shrubs (Frangula alnus and Sorbus aucuparia) and saplings of 2 species (Quercus robur and Picea abies) occurred before the surface fire. Only Frangula alnus was growing in the burned area.

In total 9 herbaceous and dwarf shrub species occurred in ground vegetation before surface fire (Table 1). Meanwhile, in the burned area the number of species increased and comprised 15 species. Dwarf shrubs such as Vaccinium myrtillus and V. vitis-idaea were the most abundant in the control area. These dwarf shrubs declined after surface fire, however recovered quite rapidly, especially Vaccinium myrtillus.

Herbaceous species of Calluna vulgaris, Luzula pilosa and Polygonatum odoratum were found only in the control site and still did not occur in 6-year-old fire site (Table 1). Rubus saxatilis, Scorzonera humilis, Calamagrostis epigeos, Pteridium aquilinum, Trientalis europaea, Peucedanum oreoselinum, Solidago virgaurea, Equisetum hyemale, Rubus idaeus occurred only in the burned area.

Only 2 moss species, Pleurozium schereberi and Hylomomum splendens, occurred before the fire in Scots pine stand (Table 1). These mosses were still absent 6 year after the surface fire. 4 new moss species (Dicranum polysetum, D. scoparium, Ceratodon purpureus, Polytrichum Juniperinum) occurred in the burned area. However, average projection cover (%) of shrubs, herbaceous, dwarf shrub, moss species in burned and control areas

Table 1. Average projection cover (%) of shrubs, herbaceous, dwarf shrub, moss species in burned and control areas

<table>
<thead>
<tr>
<th>Name of species</th>
<th>Control</th>
<th>Year after surface fire</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Shrub</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frangula alnus</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Sorbus aucuparia</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Herbs and dwarf shrubs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Callun a vulgaris</td>
<td>0.3</td>
<td>-</td>
</tr>
<tr>
<td>Convallaria majalis</td>
<td>0.6</td>
<td>+</td>
</tr>
<tr>
<td>Equisetum hyemale</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Luzula pilosa</td>
<td>0.2</td>
<td>-</td>
</tr>
<tr>
<td>Melampyrum pratense</td>
<td>0.2</td>
<td>-</td>
</tr>
<tr>
<td>Peucedanum oreoselinum</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Polygonatum odoratum</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Pteridium aquilinum</td>
<td>-</td>
<td>0.9</td>
</tr>
<tr>
<td>Rubus idaeus</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Rubus saxatilis</td>
<td>-</td>
<td>0.8</td>
</tr>
<tr>
<td>Scorzonera humilis</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Solidago virgaurea</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Trientalis europaea</td>
<td>-</td>
<td>0.1</td>
</tr>
<tr>
<td>Vaccinium myrtillus</td>
<td>17.5</td>
<td>2.7</td>
</tr>
<tr>
<td>Vaccinium vitis-idaea</td>
<td>13.4</td>
<td>0.4</td>
</tr>
<tr>
<td>Mosses</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dicranum polysetum</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Dicranum scoparium</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Hylomomum splendens</td>
<td>35.7</td>
<td>-</td>
</tr>
<tr>
<td>Pleurozium schereberi</td>
<td>60.5</td>
<td>-</td>
</tr>
<tr>
<td>Ceratodon purpureus</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Polytrichum Juniperinum</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Skre (Skre et al., 1998) found that the abundance of Calluna vulgaris, Polytrichum, Deschampsia flexuosa and Pteridium aquilinum increased after the fire in pine forests of western Norway. Regrowth of Vaccinium myrtillus and V. vitis-idaea was slower. Other studies showed (Ryoma and Laaka-Lindberg, 2005) that Ceratodon, Funaria, Pohlia nutans, Polytrichum spp. appears quickly after the fire in boreal forests. The study of post fire recovery of species in Scots pine forest in the central part of the Kola Peninsula (Gorshkov and Bakkal, 1996) showed that the herb and dwarf shrub layers recovered within 5-15 years after the fire while the mosses recovered within 90-140 years after the fire. Our study showed that surface forest fire had considerable effect on ground vegetation coverage. Fire destroyed above-ground part of vegetation, but the herbs and dwarf shrubs quite rapidly recovered within 3-4 years. The recovery of moss layer was much slower. Moss layer recover more than after 10 years (Marozas et al., 2007; Parro et al., 2009).
Conclusions

Surface fire has destroyed above-ground part of ground vegetation in pine forests. Ground vegetation began to recover in the subsequent years. 3-4 years after the fire the burned sites had even higher number of species and ground vegetation coverage than in unburned areas. The pioneer herb species and dwarf shrubs (Vaccinium myrtillus) spread out. The prevalent species of forest mosses were still absent in burned area 6 years after fire.

References


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The Consequences of the Forest Fire in Sphagnosa Forest Site Type Ecosystem

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Abstract

The outstanding and character of forest fires are predicted by the interaction of the meteorological conditions, topography as well the site and forest stand peculiarities. In Latvia since 1990 there have been at an average 850 forest fires every year. The forest site type Sphagnosa is characterising by at least 30 cm thick peat layer and with unfortunate soil moisture and aeration regime. The Sphagnosa forests take 1.4% from the total forest area of Latvia. The forest stand is formed by unproductive pine (Pinus sylvestris L.) with site index V with some birch admixture. Because of strong suffering during the forest fires, already two or three years after the burning the trees dry up and fall down.

There is a natural regeneration with pubescent birch (Betula pubescens Ehrh.) permissible in Sphagnosa forest site type, because after the fire there begins the paludification process in the burned area and the birch increases the water transpiration thus improving the growth conditions for the natural regeneration of pine.

The research is carried out in 2010 in the Forestry Rietumvidzeme of the Joint stock company “Latvian state forests”. The purpose of research was to evaluate the process of natural regeneration after the subsurface fire in the Sphagnosa forest ecosystem 2, 6, 10 and 16 years after the burning by comparing of different areas burned in the past.

Two years after the forest fire all old trees dried up in the burned area. The main tree species of young growth are: birth with 5200±478 trees per hectare, average height 0.29±0.026 m; pine - 800±289 trees per hectare, average height 0.04±0.010 m. The stand composition is 9Birch 2year,1Pine 1year with 6000±558 trees per hectare.

Six years after the forest fire the main tree species are: birch with 5540 trees per hectare, average height 1.15±0.076 m; pine - 2670±249 trees per hectare, average height 0.41±0.031 m and stand composition 7Birch 3Pine 1year. The total number of trees per hectare is 8210±529.

Ten years after the forest fire the main tree species are: pine with 3430±622 trees per hectare, average height 0.93±0.092 m; birch - 2230±211 trees per hectare, average height 1.36±0.069 m. The stand composition is 6Pine 4Birch 1year with the 5660±614 trees per hectare.

Sixteen years after the forest fire the main tree species in forest stand is pine. The tree stand composition is 8Pine 2Birch 1year, with the total number of 7310±876 trees per hectare, from which 5490±779 trees per hectare are pines with the average height of 1.99±0.142 m. The number of birch is 1830±408 trees per hectare with the average height of 1.96±0.117 m.

There was no significant differences found between the total number of trees in burned areas of different ages in Sphagnosa forest site type ($F_{stat}=0.5283\pm F_{crit}=4.7571$, $p=0.6791>p=0.05$). During the inventory in the young growth areas there have been damages found caused by pine bud moth (Blastestia turionella Hb.) in sixteen years old burned area in amount of 3.1% and the damages of pine resin-gall moth (Petrova resinella L.) in ten years old burned area in amount of 2.6% and in sixteen years old burned area in amount of 6.3%. There were only the branches and buds of damaged.

The fire as a natural disturbance promotes forming of gaps in the layer of tree stand canopies, thus supporting favourable conditions for the natural regeneration of forest. At the age of 16 years the average height of pine and birch is almost similar reaching for pine 1.99±0.142 m and for birch - 1.96±0.117 m.

Key words: forest fires, Sphagnosa forest site type, forest regeneration, Pinus sylvestris L., Betula pubescens Ehrh.

Introduction

The forests are suffering from the different nature disasters for a long time, int. al., from the forest fires (Bušs 1989). The outstanding and character of forest fires are predicted by meteorological condition, topography and site specific. The fire is significant ecological factor. The cause of the outstanding of forest fire in main cases is a conscious or unconscious action of a man (Тіаченко 1955, Liepa et al. 1991). Since 1990 in the Latvia there have been at an average 850 forest fires occurred every year. The highest amount of forest fires has been in 2006, when 1925 fires have been registered and 3370 hectares of the forest burned. In 2002 there were 1742 forest fires with 2364 hectares burned, in 1998 - 356 forest fires with 211 hectares burned, but in 1992 - 1510 forest fires with 8412 hectares burned (the statistical information of State Forest Service). The forest fires are divided in the surface fire, crown fire and subsurface fire. In peatland forests on wet peat soils in dry summers there occurs the subsurface fire (Vanags 1987).

The possibility of outstanding of the process of forest fires depends also on forest peculiarities. The combustibility of forests is impacted of the amount of deadwood. The amount of decendent timber volume in pine forests of Sphagnosa type (5.1±0.64 m$^3$ ha$^{-1}$) is one of the lowest (Jansons 2010). Important factors in the spreading process of forest fire are the plants of the ground cover vegetation. In the 1st floor of the ground cover vegetation in Sphagnosa forest site type mostly grow the common heather (Calluna vulgaris (L.) Hill.), hare's-tail cottongrass (Eriophorum vaginatum L.), marsh labrador (Ledum palustre L.), bog bilberry (Vaccinium uliginosum L.), bog-rosemary (Andromeda polifolia L.) and others, including the underwood species. The flames can reach the height between 1.0 and 1.5 m. In the 2nd floor of the ground cover vegetation grow the juniper haircap moss (Polytrichum juniperinum Hedw.) and different peat moss (Sphagnum) species. On the hillocks there grow the big red stem moss (Pleurozium schreberi (Br.) Mill.), wavy broom moss (Dicranum polysetum Mich.) and different reindeer lichen's (Cladina) species. During the dry weather conditions the ground cover of lichens and mosses starts to burn well and rapidly. The height of flames reaches 0.3 - 0.5 m. The moisture of the burning material is of high importance. The fresh and moist decaying material burns slower if to compare to old and dry material. The decomposition rate of decaying material decreases its combustibility (Nesterovs 1954, Bušs 1981). The soil, mostly its moisture, radically impacts the outstanding of forest fires. There is less combustibility in forest stands on wet peat and hydro-morph mineral soils. The fires eliminate forest resources, devastate forest ecosystem and do considerable losses for land economy. The fire damages or totally destroys the living trees, shrubs and ground cover vegetation. There is dying the living fauna and the silviculcultural activities are disturbed (Vanags et al. 2004).
The Sphagnosa forest type is characterising by the peat soil and very unfortunate soil moisture circumstances during the autumn, winter and spring. The Sphagnosa site type forests takes 1.4% from the total area of forests in Latvia with the total amount of timber 110 m³ ha⁻¹ (Zālītis 2006). The peat consists of the unfertile, strongly acid peat moss with the admixture of residues of pine, cottongrass and shrubs. The thickness of the peat moss layer reaches 20 cm in the soil surface. In the low productive pine (Pinus sylvestris L.) stands with site index V, there is some birch admixture usually. The waterlogged peat soils are poorly aerated as in wet so in dry summers. The thickness of the organic soil surface horizons and the peat layer exceeds 30 cm (Bušs 1981). The taproots of pines growing on peat are reduced. The lateral roots are concentrated near to soil surface and therefore are strongly suffering during the fires. Already two or three years after the fire the pines dry up and fall down. There, in the moderate climate zone, the most important pioneer tree species is the birch, which is growing almost in every habitat (Bušs 1989). The pubescent birch (Betula pubescens Ehrh.), known also as downy birch, is often considered as a slower growing and not desirable tree species. Naturally, it is growing mostly on the waterlogged, peaty soils. The abundance of birch as an excellent transpirator of water in the stands of conifer tree species is considered as a prerequisite for survivability of the waterlogged forests. There can be found the natural structure of waterlogged forests in the mixed stands of conifers and birch (Zālītis et al. 2003).

The ecological investigations of burned areas are important because of two reasons. One of them is the impact of fire as a stressor on the plants survived after the fire event, as well the natural succession after the fire. The second reason sounds that forest fires are even necessary for the exchange of the nutrients between the soil and living biomass. The tree species have a not overestimated importance for the cycles of chemical elements and energy in the biosphere. The forests take less than ¼ of the terrestrial area, but produce more than ½ from the amount of atmospheric oxygen. The forests of the world synthesise ⅓ from the total organic mass produced over terrestrial area. The green plants during the photosynthesis process absorb the solar energy so fulfilling an important cosmic role. No other living organisms have similar height and lifespan as the trees. Therefore, the importance of forest ecosystems increases in the integrated research projects of the biosphere dynamics. In this case the aim of research is to analyse the process of the natural regeneration process of the forest after the subsurface fire in the Sphagnosa forest ecosystem in areas burned two, six, ten and sixteen years ago. To accomplish the aim, the following tasks were proposed: 1) to analyse the dynamics of tree number and growth rate; 2) to evaluate the process of the natural regeneration after the forest fire.

Research methods

The research is carried out in the Forestry Rietumvidzeme of the Joint stock company “Latvian state forests”. In the Region Limbaži and the Region Cēsis, where there is the highest amount of precipitation, the snow cover remains longer and the spring entries later. The precipitation in the forests of the region has a slightly acid pH. The research data have been collected about the regeneration process in four forest stands of Sphagnosa type burned two, six, ten and sixteen years ago respectively. The first forest stand takes 0.6 hectares and is located in the Nature Reserve “Ziemeļu purvi” in the area of North Vidzeme Biosphere Reserve (co-ordinates x, y: 556639.3, 6427536.8). The area is supervised by Forestry Mazsalaca of the Ziemeļvidzeme Forest District of the State Forest Service. This forest stand has burned in the summer of 1992. The total area burned is about 80 hectares. The second forest stand takes 1.1 hectares and is located in Forestry Katvari of Riga region Forest District (co-ordinates x, y: 534466.2, 6394417.0). The forest fire has been there in the summer of 1998, taking 79 hectares in total. The third forest stand with the area of 2.2 hectares is located in Forestry Mazsalaca (co-ordinates x, y: 568346.1, 6415981.3), being burned in the summer of 2002. The total area burned is 15 hectares. The fourth forest stand with the area of 0.7 hectares is located in Forestry Katvari (co-ordinates x, y: 536413.8, 6394385.3) and burned in summer of 2006. The total area burned is 12 hectares.

There were sample plots with the size of 25 m² (10 x 2.5 m) established for the estimation of the height and the number of trees. The sample plots were placed on the longest diagonal of the forest stand area. In the first stand researched there were 7 plots, in the second – 7 plots, in the third – 15 plots and in fourth stand – 7 plots established. For the control of the current location in the certain forest stand, a GPS (Global positioning system) receiver was used. In total, there were 36 plots established, where the trees were counted for each species. For each species there was the height for 30 trees measured by tape with precision of 0.01 m. The trees placed more than 50 cm distant each from the other were counted for each species. The health condition of the trees was evaluated visually, using the characteristics of insects and diseases by different authors (Amann 1965, Millar 1975, Plise 2007, Jansons et al. 2008).

According to data of the inventory, the number of trees (N, trees per hectare) was calculated for each species by equation 1:

$$N = \frac{\sum_{i=1}^{i} n_i \cdot 10000}{L},$$

where

- $n_i$ - the number of trees according to inventory data of i-th sample plot,
- $L$ - the area of sample plot, m²,
- $i$ - the number of plots established in the forest stand, pieces.

1987, Rivža 2005). There, in the Sphagnosa forest site type, the clearcut- and burning areas rapidly become overgrown by heather and often transform to raised bogs (Liepa 2003).
Summing the number of trees of both tree species on a hectare, there is the total number of trees (trees per hectare) on the hectare achieved. The average tree height of forest stand \( H_{\text{average}} \) (m) for each species was calculated by equation 2:

\[
H_{\text{average}} = \frac{H_1 + H_2 + \ldots + H_i}{i},
\]

where \( H_1, H_2, H_i \) - tree height, m.

In the research, there is the growth course of the natural regeneration of pine and pubescent birch compared after the subsurface fires in the Sphagnosa forest site type, comparing the number and height of trees.

There has been the Pearson correlation analysis and the variance analysis used for the evaluation of the natural regeneration of pubescent birch and pine in Sphagnosa forest site type 2, 6, 10 and 16 years after the fire. The arithmetical mean and standard error of mean (\( \bar{x} \pm s \)) has been calculated with MS EXCEL program by confidence level of 95\% (Arhipova & Bāliņa 2003).

Results and discussion
The dynamics of tree number and growth course

The fire is wide scale disturbance, simultaneously creating considerable changes in the whole forest stand area (Bušs 1989). Two years after the fire the trees in the burned area have dried out and a part of them are torn up by the roots. It corresponds to previously performed researches that the probability of the loss of the uncovered burned roots during the four next years is 100\%, independent from the tree dimensions (Никитин & Рубцов 1986, Donis 2010). According to measurements it can be concluded that in Sphagnosa forest site type two years after the fire there takes place the natural regeneration by pubescent birch (Betula pubescens Ehrh.), which reaches the height of 29±0.026 cm and the tree number of 5200±478 per hectare. After the devastating impact of fire, there, in the forest stand area, changes regime of light, moisture and temperature. In the result of fire there appear the preferences for species with fast growth course – pioneer species, which are very important for growth course of the natural regeneration of forest (Bušs 1989). In this case such species is the pubescent birch. Between the birches there grows also 3 – 5 cm long seedlings of the pine (Pinus sylvestris L.) with the average height of 0.04±0.010 cm and the number of trees 800±289 per hectare (Figure 1). The spreading of the pine seeds is irregular, which is confirmed by fact that in the 3 plots from the seven the seedlings were not present. The forest stand composition is 9Birch 2 years 1Pine 1 year with the total number of trees 6000±558 per hectare. In the moment of measurement there were no damages found made by insects and diseases.

There, in the forest stand, six years after the fire, the pubescent birch reaches the average height of 1.15±0.076 m with the number of trees of 5540±378 per hectare. Correspondingly, the average height of pine is 0.41±0.031 m and the number of trees - 2670±289 per hectare (Figure 2). The number of pubescent birch trees per hectare is two times higher as for pine in the area six years after the forest fire. However, the average height of trees is 2.8 times lesser. The forest stand composition is 7Birch 3Pine 6 years, with the number of trees 8210±529 per hectare. There were no damages found made by insects and diseases.
Ten years after the fire, the birch has reached the average height of 1.36±0.069 m and the number of trees was 2230±211 per hectare. In its turn, the average height of pine was 0.93±0.092 m and the number of trees was 3430±622 per hectare (Figure 3). In the area of natural regeneration, the number of pubescent birch on a hectare decreases in relation to the number of pine. However, the average height for pine is of 0.43 m less than those for pubescent birch. The forest stand composition is 6P4B_{10} with the total number of trees of 5660±613 per hectare. Evaluating the vitality condition of trees visually, there were non significant (2.6%) damages of pine resin-gall moth (*Petra resinella* L.) found. The damages caused by diseases were not found.

In the forest stand of *Sphagnosa* forest site type, sixteen years after the forest fire the pubescent birch has reached average height of 1.96±0.117 m and the number of trees of 1830±408 per hectare. In its turn, the average height of pine was 1.99±0.142 m with the number of trees of 5490±779 per hectare (Figure 4). The composition of forest stand is 8P2B_{16} with the total number of trees of 7320±876 per hectare (Figure 4).
It means, that sixteen years after the forest fire in the area of natural regeneration the number of pine overtakes those of pubescent birch in 3 times and the average height of pine is 0.03 m higher than those for birch. Evaluating the vitality condition of trees visually, there were some damages of pine bud moth (*Blastesthia turionella* Hb.) (3.1%) and of pine resin-gall moth (*Petrova resinella* L.) (6.3%) found. These damages are not significant for a young growth, because only the branches and buds of branches are damaged.

**Evaluation of the process of the natural regeneration after the fire in the Sphagnosa forest site type**

K.Bušš (1989) suggests, that in the forests, reached the climax stage, almost all nutrients of plants are bounded in living biomass or in humus. Only a small part of nutrients are circulating between the soil and living organisms. During the forest fire there is being destroyed the O horizon of the soil, the soil acidity decreases, as well the several chemical compounds releases, which turns to forms available for the plants. In this case, the forest fire acts as an enabling factor, helping release the nutrients bounded in humus. In the cases – two and six years after the fire in *Sphagnosa* forest site type, there mostly the natural regeneration with pubescent birch proceeded (Figure 5). The pubescent birch protects the burned area from the paludification, as from 1 kg of the birch leaves, there, during the growing season (May-October), evaporates 400 l of water (Zālītis et al. 2003), thus promoting also the growing of pine. The natural regeneration in *Sphagnosa* forest site type is successful (Figure 5). The Regulations Nr. 1453 of the Cabinet of Ministers of the Republic of Latvia prescribes, that there, in the *Sphagnosa* forest site type, the regeneration with pine and birch is permissible with the term of not more than 10 years after the cut or impact of other factors. The maximal number of young trees in *Sphagnosa* forest site type is not limited. However, in spite of Regulations, I.Liepa (2003) indicates, that the target species in *Sphagnosa* forest site type is pine.

The measurements of the number (Figure 5a) and the height (Figure 5b) of trees, showed in diagram, suggest that after the fire, the regeneration of pine proceeds very dynamically. If in the first two years after the fire there are only 800±289 pine seedlings per hectare, then after the sixteen years - 5490±779 pine trees per hectare with the average height of trees of 1.99±0.142 m. The good growth and big number of birch trees was monitored in the areas burned two and six years before. The number of birch trees in natural way, without any silvicultural activity of man, reduces from the 5200±478 trees per hectare till the 1830±408 trees per hectare and the average height of trees reaches 1.96±0.117 m.
There exist no significant differences between the total number of trees in the burned areas of different age in *Sphagnosa* forest site type (*F* =0.528< *F* crit.=4.757, *p*=0.679>*p*=0.05). In its turn, there is close positive correlation (*r*=0.99, *p*=0.05) between the age of burned area and the number of pine trees established.

The natural regeneration, taking in to account the number of trees, is successful and the young growths correspond to the criteria of a regenerated area. There have been only non significant damages of insects and diseases impacting the vitality condition of trees found.

**Conclusions**

In spite of the fact, that the forest fire destroys the forest resources, makes big damages to the forest biocenosis, brings the considerable losses to the national economy and pollutes the atmosphere, the forest fires have also a positive impact. There is being promoted the exchange of nutrients between the soil and living biomass. There proceeds the paludification of the burned area. Under the birches, there sows also the pine (*Pinus sylvestris* L.), which certain time jogs along with the pubescent birch. Because of nutrient pure peat soil and of waterlogged conditions, there, at the age of sixteen years, the growth of birch begins to drop behind of pine and the area is taken by pine.

The natural regeneration with the pubescent birch proceeds evenly in the area. The number of naturally regenerated birch trees in the forest stands with different age in all sample plots was between 1422 and 5918 trees per hectare. The natural regeneration of pine is more unevenly. The pine trees are abundant in 83.3% of the sample plots. The number of naturally regenerated pine seedlings in the area, two years after the fire, not exceeded 1089 trees per hectare. The natural regeneration with the pubescent birch proceeds numerically more successful. The numerical prevalence of pine has been found in one research object – in the sixteen years old burned area, where the number of pine trees in all sample plots exceeds 3500 trees per hectare. There is no significant differences between the total number of trees in the burned areas with different age in the *Sphagnosa* forest site type (*F*=0.528< *F* crit.=4.757, *p*=0.679>*p*=0.05).

Two, six, ten and sixteen years after the forest fires in *Sphagnosa* forest site type, the forest regeneration initially proceeds with the pubescent birch, later also with the pine. Because of insufficient amount of nutrients and, also, because of waterlogged conditions, the birch, reaching the height of 1.96 m begins to drop behind the pine in growing, as well there decreases the number of birch trees in forest stand. The pine becomes the dominant tree species in the *Sphagnosa* forest site type.

Evaluating the vitality condition of trees, there were some damages of pine bud moth (*Blastesthia turionella* Hb.) sixteen years after the forest fire found in amount of 3.1%. The damages of pine resin-gall moth (*Petrova resinella* L.) ten years after the forest fire were in amount of 2.6%, but sixteen years after the forest fire – in amount of 6.3%. These damages are not significant for a young growth, because only the branches and buds of branches are damaged.

**Acknowledgments.** This research is financed through the European Regional Development Fund project "Decision support system for sustainable forest management" (No.2010/0208/2DP/2.1.1.0/10/APIA/VIAA/146).

**References**

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6. Ehrh.). The birch provides the transpiration process, which avoids the
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The natural regeneration, taking in to account the number of trees, is successful and the young growths correspond to the criteria of a regenerated area. There have been only non significant damages of insects and diseases impacting the vitality condition of trees found.

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Communities of Ground Beetles (Insecta: Coleoptera) in Places with Different Relief

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Aleksandras Stulginskis University, Lithuania
Lithuanian Research centre for Agriculture and forestry, Lithuania

Abstract

The search of ground beetles (Insecta: Coleoptera) was made in Kamša Botanical-Zoological Reserve, section no 458, plot no 5. We have chosen 5 parts of the plot for investigation: in a plane surface of the forest, on the North, the South the East and the West slopes in order to detect influence of the exposition place relief to abundance of caught ground beetles individuals and species.

The aim of investigation was to determine structure of ground beetle communities, its temporal changes and dependence on the relief of exposition place.

The Barberis ground traps were used in the research, 5 units in the each chosen part, 25 in total. The distances between the ground traps were 5 m. The trap is made from a 0.5 l volume and 6.5 cm diameter plastic cruet. The traps were dig in to ground to the top of the trap. 1/3 of the trap was filled with a 10% formalin soak. In that case the insects were saved from decomposing and birds. The collected beetles were dried and identified in the labs of Aleksandras Stulginskis University.

The total amount of collected ground beetles in 10 records, made since May to August 2012, was 1627. A variety of 15 species in 4 families Carabidae, Silphidae, Curculionidae and Staphylinidae were identified. The most abundant species collected was Phosphuga atrata – 312 ground beetles. The maximum quantity of ground beetles were caught in the plane surface of the forest, the next optimal place for ground beetles gathering was the West slope. The minimal quantity of ground beetles corresponds with the South slope.

Dynamics of caught ground beetles individuals and species abundance was registered as well. The maximum quantity for almost all species was reached in June. Some species showed the other maximum in August.

Key words: reserve, exposition place relief, ground beetles, ground trap, dynamics of abundance.

Introduction

Insects (Insecta) are the most abundant group of organisms that make up approximately 75% of all known species of animals (Pileckis, Monsevičius, 1995). According to a famous entomologist E. O. Wilson, if the insects disappeared, it would lead to the death of amphibians, reptilians, birds and mammals. This process would be followed by extinction of flowered plants and forests. The Earth surface would start rotting (Grikevičius 2009).

Beetles (Coleoptera) group is the largest group among insects and makes up around 25% of all known species of animals on Earth (Šablevičius, 2011). In the nature beetles have influence on metabolism because 90% of the forest produced biomass returns to the soil (Wolters, 2000). The role of beetles is important in the process of soil formation and to the balance of other animals. Among the beetles there are some that are harmful which may make loss during massive reproduction, transmitting plant and animal infectious agents (Žiogas and Pėtelis 2008). Some of the beetles (entomophagus) are used in biological fight against the pests. A group of bioindicator beetles may be used as indicators to determine the changes (Rainio and Niemelä 2003) in the environment or ecological processes in the forest (Buhac 1999, Rainio and Niemelä 2003).

Distribution of beetles population in different layers of the forest was investigated in some research works, and not one of them it was proved that the beetles are mostly found on the soil surface, in the upper layers of the soil and on the forest floor (Bouget et al.2008). Generally, the abundance of beetles depends on the type of the forest floor, physical and chemical its properties (Chapin et al. 2002).

Kamša Botanical-Zoological Reserve was established in 1960, its area is 320 ha. The reserves distinguished by its conformation which is carved by ravines of steep (steeper than 12°) slopes (The plan of Kamša Botanical-Zoological Reserve, 2008-2017). Deciduous stands dominate (Mirinas et al., 2007).There are 696 beetle species found: 84 species of ground beetles, 112 species of snout beetles, 76 species of leaf beetles and over 100 species of rove beetles are registered in Kamša Botanical-Zoological Reserve. In addition, eight species of beetle and two species of moth, included in the Red Data Book of Lithuania, were found in the reserve. Kamša reserve is included in the Natura 2000 ecological network of territories as a territory, valuable and protective because of the population of Cucujus Cinneberinus (Vaišvilavičius et al., 2008). Data on some beetle species in Kamša Botanical-Zoological Reserve was published in scientific journals (Vaišvilavičius et al., 2008). In connection to the fact that insects of Kamša reserve is characterized by a very large variety of species, in fact, it is almost impossible to cover all the insects of the territory and to study them sufficiently. For this reason research of ground beetle (Coleoptera) species from the forest floor were chosen. The task was to evaluate the dynamics of ground beetle activity and to distinguish the beetle species that dominate in the reserve.

Material and methods

Particular specific features, distinctive research methods that are required by a large beetle species variety, diverse habitat, and complex cycle of development are typical to the research of insects. Our investigation was carried out in Kamša Botanical-Zoological Reserve, section no 458, plot no 5. Considering the features of conformation of the studied territory, 5 study plots were selected that are in the slopes of north, south, east and west exposition and in the even area of the forest. Barber traps (0.5 l plastic jar of 6.5 cm diameter opening, dug into the ground, levelled with its
surface) were used for the catch (Фасулати, 1971). In every plot 5 traps were fitted, filling 1/3 of the trap with 10% formalin solution. The traps were used from 1 May until 24 August 2012. Every 10 days the traps were emptied, the beetles that were inside were taken to plastic jars specially designed for this purpose and fixed with 70% ethanol solution. After this, the jars were labelled and transported to the laboratory for the analysis.

In the laboratory a binocular microscope MБС-1 and various other types of identification manuals, as well as standard collections of T. Ivanauskas Zoology Museum were used. Collected beetles were described to the species. Obtained data was analysed using Microsoft Excel 2003 software programme.

The beetles distribution characterized by:
1. Structure of beetle communities and number of species;
2. Relative abundance (PI) of species caught in collection:

\[ PI = \frac{n_i}{N} \]

- \(n_i\) –number of is species beetles in collection
- \(N\) – total number of beetles in collection

According to well-known method (Gorny, Grum 1981) the species were subdivided in to 5 classes of abundance relative (Table 1).

### Table 1. Beetles distribution to relative abundance (dominance) classes

<table>
<thead>
<tr>
<th>Grade</th>
<th>Classes</th>
<th>Classes of dominance</th>
</tr>
</thead>
<tbody>
<tr>
<td>D5</td>
<td>PI≥10%</td>
<td>Eudominant species</td>
</tr>
<tr>
<td>D4</td>
<td>10%&gt;PI≤5%</td>
<td>Dominant species</td>
</tr>
<tr>
<td>D3</td>
<td>5%&gt;PI≤2%</td>
<td>Subdominant species</td>
</tr>
<tr>
<td>D2</td>
<td>2%&gt;PI≤1%</td>
<td>Recedent species</td>
</tr>
<tr>
<td>D1</td>
<td>PI&lt;1%</td>
<td>Subrecedent species</td>
</tr>
</tbody>
</table>

The confidence intervals of the estimates were obtained by employing one–way analysis of variance by ANOVA (in case of significant interactions) followed by post hoc Turkey theoretical criterion. The least significant differences between treatment means were determined using Fisher’s least significant differences (LSD\(_{05}\)). LSD, standard error (SE) has been calculated at level of statistical significance \(p < 0.05\).

**Results and discussion**

The total amount of collected ground beetles in 10 records, made since May to August 2012, was 1627. A variety of 15 species (Table 2) in 4 families *Carabidae* 721 – 44.6%, *Silphide* 588 - 36.1%, *Curculionidae* 165 – 10.1% , and *Staphylinidae* 149- 9.2% was identified. (Fig.1).

### Table 2. 15 species identified in Kamša Botanical-Zoological Reserve, section no 458, plot no 5

<table>
<thead>
<tr>
<th>Family</th>
<th>Species</th>
<th>Species abundance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ind.</td>
<td>%</td>
</tr>
<tr>
<td><em>Carabidae</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Carabidae</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Platynus assimilis</em></td>
<td>97</td>
<td>6.37</td>
</tr>
<tr>
<td><em>Carabidae</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Pterostichus niger</em></td>
<td>131</td>
<td>8.30</td>
</tr>
<tr>
<td><em>Carabidae</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Cychrus caraboides</em></td>
<td>28</td>
<td>1.83</td>
</tr>
<tr>
<td><em>Carabidae</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Carabus coriaceus</em></td>
<td>96</td>
<td>6.30</td>
</tr>
<tr>
<td><em>Carabidae</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Carabus granulatus</em></td>
<td>147</td>
<td>9.71</td>
</tr>
<tr>
<td><em>Silphidae</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Necrophorus investigato</em></td>
<td>65</td>
<td>4.26</td>
</tr>
<tr>
<td><em>Silphidae</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Phosphuga atrata</em></td>
<td>312</td>
<td>20.50</td>
</tr>
<tr>
<td><em>Silphidae</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Oiceoptoma thoracica</em></td>
<td>146</td>
<td>9.60</td>
</tr>
<tr>
<td><em>Silphidae</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Necrophorus vespoloides</em></td>
<td>105</td>
<td>6.90</td>
</tr>
<tr>
<td><em>Silphidae</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Dendroxena quadrimaculata</em></td>
<td>1</td>
<td>0.06</td>
</tr>
<tr>
<td><em>Curculionidae</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Otiorhynchus ligustici</em></td>
<td>25</td>
<td>1.64</td>
</tr>
<tr>
<td><em>Curculionidae</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Sciaphilus peratus</em></td>
<td>14</td>
<td>0.92</td>
</tr>
<tr>
<td><em>Curculionidae</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Barypithes trichopterus</em></td>
<td>110</td>
<td>7.20</td>
</tr>
<tr>
<td><em>Staphylinidae</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Londithon lunulatus</em></td>
<td>24</td>
<td>1.57</td>
</tr>
<tr>
<td><em>Total</em></td>
<td></td>
<td>1627</td>
</tr>
</tbody>
</table>

Dominance data are presented as percentage scares of individual species in a community. The following classes of dominance D are used: D5 – eudominant species: (proportion of individuals PI≥10%), D4 – dominant species: 10%>PI≤5%, D3 – subdominant species: 5%>PI≥2%, D2 – recedent species: 2%>PI≤1%, D1 – subrecedent species: PI<1% (Gorny, Grum 1981).
Figure 1. Composition and abundance of caught ground beetles families in forest floor

The most abundant of caught beetles were eudominant species Phoshuga atrata by 312 ind. or 20.5 %. The second was Carabus nemoralis of D5 classes of dominance presented by 225 ind. or 14.8 %.

Dominant species D4 were 7 species: Carabus granulatus - 147 ind. and 9.7 %, Oiceoptoma thoracica - 146 ind. and 9.6 %, Pterostichus niger - 131 ind. and 8.3 %, Barypithes trichopterus - 110 ind. and 7.2 %, Necrophorus vespilloides - 105 ind. and 6.9 %, Carabus coriaceus - 96 ind. and 6.4 %, Platynus assimilis - 97 ind. and 6.3 %.

Subdominant species D3 Necrophorus investigato found 65 ind. and 4.3 %. Recedent species D2 were composed of 3 beetles species: Cychrus caraboides (28 ind. and 1.8 %), Otiorhynchus ligustici (25 ind. and 1.6 %), Lordithon lunulatus (24 ind. and 1.6 %), subrecedent species D1 - Sciaphilus asperatus - 14 ind. and 0.9 %, Dendroxena quadrimaculata - 1 ind. and 0.06 %. D. Only one Quadrima culatafell into the trap, but it is important to mention, because it belongs to the species included in the Red Book of Lithuania.

The most surprising in our investigation was the difference in relative abundance of species caught in different study plots (Fig. 2).

The maximum quantity of ground beetles were caught in the plane surface of the forest, the next optimal place for ground beetles gathering was the West slope. The minimal quantity of ground beetles corresponds with the South slope.

Eudominant species D5 - Phoshuga atrata, and the second plurality – dominant species D4 - Pterostichus niger was in the plane surface of the forest. Eudominant D5: Phoshuga atrata and Carabus nemoralis were in the West slope.

In investigation the largest part of the catch was dominant species. They were 7: Carabus granulatus, Oiceoptoma thoracica, Pterostichus niger, Barypithes trichopterus, Necrophorus vespilloides, Platynus assimili sand it was 46.67 %, dominant species identified beetles were (832 ind.), it was 51,14 % of total 1627 ind.

The smallest numbers of individuals 2 corresponds to subdominant species: Sciaphilus asperatus, Dendroxena quadrimaculata.

Two species – Phoshuga atrata, Carabus nemoralis were ascribed to eudominant - 35.3 % from total numbers of beetles. Subdominant species was Necrophorus investigato - 4.3 %.

The total number of Carabidae caught was 721 ind., 6 different species were identified. The difference in relative abundance of species caught in different study plots revealed (Fig. 3).
Figure 3. Average number of Carabidae per trap during the season for species (reference on the right) depending on the research plot (mean±SE)

The most of Carabidae was Carabus nemoralis 226 ind. or 31.3 % of total number of Carabidae caught. It is important to mention C. coriaceus, because it belongs to the species included in the Red Book of Lithuania. We have identified 96 C. coriaceus ind. in our investigation.

As it regards Silphidae we have identified 588 ind. and they were distributed into 5 species. (Fig.4).

Figure 4. Average number of Silphidae per trap during the season for species (reference on the right) depending on the research plot (mean±SE)

We want to pay attention to very small number of Silphidae, caught in slope of north exposition, compared with other families. The most abundant species collected was Phosphuga atrata – 312 ground beetles.

The last described family is Curculionidae: we have identified 149 ind. and they were distributed into 3sp.: Barypithes trichopterus - 110 ind., Otiorhynchus ligustici - 25 ind., Sciophilus asperatus - 14 ind. (Fig. 5).

Figure 5. Average number of Curculionidae per trap during the season for species (reference on the right) depending on the research plot (mean±SE)

Dynamics of caught ground beetles individuals and species abundance was registered as well. The research was performed since May to August 2012. The number of collected ground beetles was recorded and the obtained data was analysed in order to assess the number of collected beetles on the dependency on month.

During the period of May and June almost in all exposition places the number of collected ground beetles was larger, comparing with later beetle records. Such number of collected individuals could depend on several factors that had influence, such as environment conditions, beetle migration in spring and physiological processes. The second slight increase of abundance was observed in August (Fig. 6).
Conclusions

During the research in section 458, plot 5 of Kamša Botanical-Zoological Reserve in total were found 1627 beetles (Coleoptera), belonging to 15 species and 4 families, namely Carabidae, Silphidae, Curculionidae, Staphylinidae.

The abundance of collected beetles depended on the exposure of the slope. The least number of collected beetles was in northern slope of the studied plot. In all the other studied plots the abundance of beetles was almost equal.

Majority of ground beetles were collected in the even forest area, in total 446 individuals. The largest part of ground beetles Carabidae was collected in the even area of the forest – 182 individuals and Silphidae – 196 individuals. The numbers of collected Curculionidae were equal – 35 individuals in both areas: in the traps located in the northern slope and in the even area of the forest. The largest number of Staphylinidae family members was collected in the traps located in the northern slope – 54 individuals.

The most common and classified to the eudominant species – Phoshuga atrata – 312 individuals and it made up 20.5 % of all the number of collected beetles. The second according to the abundance was Carabus nemoralis - 225 individuals and it made up 14.8 %. 7 species were classified as dominant species. One subdominant species was distinguished. 3 species depended on recendent species. 2 species depended to subrecendent species.

The abundance of ground beetles collected in the studied territory increased in May and June and reached maximum in the middle of June. The second slight increase of abundance was recorded in August. Such an increase in the abundance in the end of the summer may lead to the assumption that particular species Pterostychus niger hibernate in the larval stage, and other species, for instance Carabus coriaceus, is only active in spring because it hibernates in the imago stage.

References

Drainage Water Quality Evaluation by Fertilizing Fields with Manure from Large Livestock Enterprises

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Aleksandras Stulginskis University, Lithuania

Abstract

The research was conducted during the years 2008-2012 in the drained fields fertilized by stockbreeding farms’ manure, where 2 variants were installed: fertilized and unfertilized fields. The field was fertilized with manure every spring, in which according to the fertilizing value of manure, the following contents of total nitrogen passed into manure-fertilized fields in each year: 2008 – 169 kg ha⁻¹, 2009 – 168 kg ha⁻¹; 2010 – 169 kg ha⁻¹; 2011 – 169 kg ha⁻¹; 2012 – 170 kg ha⁻¹. Maize for cattle forage was grown in experimental fields.

The soil of the research subject is sandy loam. In the layer 0-40 cm of the fertilized area, the humus content in the soil fluctuated from low (1.2 %) to high (4.9 %). The content of mineral nitrogen fluctuated from 14.2 to 289 kg ha⁻¹ what corresponded to the nitrogen content very low and very high respectively. The content of humus in non-fertilized soil fluctuated from the very low value (1 %) to moderate value (3 %). The content of mineral nitrogen fluctuated from 10.9 to 130 kg ha⁻¹, what corresponded to the nitrogen content very low and very high.

For the purpose of chemical investigations, water samples from drainage were taken once per month. Water analyses were carried out by the accredited Chemical Analytical Laboratory of the Water Management Engineering Institute of Aleksandras Stulginskis University.

N$_{\text{total}}$ in drainage water was determined by applying the spectrometric method, by mineralizing with potassium persulphate.

Soil samples for agrochemical investigations were taken monthly from the depth of 0-60 cm at every 20 cm. To identify the content of nitrogen in the soil, the following research methods were applied: ammonium nitrogen (N-NH₄⁺) – colorimetric with Nessler’s reagent in KCl extract; nitrate nitrogen (N-NO₃⁻) — potentiometric with selective electrode. Analyses of N – NH₄⁺ and N – NO₃⁻ were carried out by means of analyser “FIA Star 5012”.

The composition of manure was identified from one extract prepared by burning with concentrated sulphuric acid (H₂SO₄) and selenium (Se) catalyst. Nitrogen was identified using Kjeldal method, by mineralizing with a mineralizer “Digestor 2006” as well as distilling with a distiller “Kjeltec System 1002 Distilling Unit”.

To determine the rainfall and air temperature, data from Dotnuva Meteorology Station were used.

The aim of this research was to ascertain the impact of large livestock company fields fertilized annually with manure on the water quality in drainage.

Investigation results have demonstrated that fields fertilized annually with manure raised the contents of N$_{\text{total}}$ in the soil by 1.5 times respectively in comparison to the non-fertilized variant. The increase in these contents was conditioned by the higher air temperature and the lower rainfall. The seasonality of N$_{\text{total}}$ concentrations in drainage water was discovered: higher concentrations were identified in autumn and winter, lower concentrations – in spring and summer.

Keywords: drainage water, soil, concentration, manure.

Introduction

Nutrient leaching is typical for all Baltic states of oceanic climate, including Lithuania. In Lithuania, the main source of nutrient input into the Baltic Sea is the river Nemunas and its smaller tributaries. As it was determined, the largest amounts of mineral nutrients enter the sea in winter, while in summer the inflowing amounts of the elements are significantly less. The second largest values of inorganic nitrogen due to the effect of the flood water were observed in spring (Dubra et al., 1999). During the later research it was established that in Lithuania the largest amounts of mineral nitrogen were transported during autumn-winter season. 51.7% of the annual flow amount on average were transported in the rivers of Southern Lithuania, 51.9% – in the rivers of Central Lithuania and 65.4% – in the rivers of Western Lithuania (Bagdžiūnaitė – Litvinaitienė, 2005).

Due to new manure handling technologies, litter-free manure and liquid manure are prevailing in the intensive production livestock farms. The content of nutrients in such types of manure is considerably lower than in litter manure. Obviously, the fertilization with manure raises the contents of humus and nutrients in the soil, however, under conditions of plenty fertilization, the wash up of nutrients through drainage into streamlets is more intensive. It was determined by means of researches that 30–35 % of nitrogen and 10–15 % of phosphorus passing into surface water bodies are from agricultural sources (Staniszweska and Shung, 2002).

It was ascertained that the wash up of nitrogen is highly influenced by natural factors, soil composition, density of raised livestock, content of meadow, farming activities in the drained area, season, and mostly by local factors (Kyllmar et al., 2006; Morkūnas et al., 2005). It was determined that the diffused water pollution is directly related to the used quantities of fertilizers, grown plants, and the overall culture of farming (Meissner et al., 1998). It was ascertained by Finnish scientists that the water quality of small streamlets depends more on seasonal meteorology than on changes in land production structure or technology (Vuorenmaa et al., 2002). Similar results are also announced by other scientists stating that seasonal meteorology has a considerably higher impact on the wash up of nitrogen than the diverse land exploitation practice (Stalnacke et al., 2002). Continually grown plants of one species induce also the higher migration of nitrogen in the soil (Bakhsh et al., 2001). However, the periodical fertilization with manure improves considerably properties of the soil with a light granulometric composition (Tripolskaja and Šidlauskas, 2010).

Large quantities of manure accumulate in large livestock companies, where many animals mass in one place. The spread of manure in fertilized fields affects the surface water as a diffused pollution. There are some cases, where due to high transport costs companies are used to spread manure in the same fertilized areas not far from farms every year. The danger is that fields may become over-fertilized and many nutrients may be washed up into the environment. The pollution of drainage water is most possible when the rain falls after fertilization with manure (Smith et al., 2001).
The aim of this research was to ascertain the impact of large livestock company fields fertilized annually with manure on the water quality in drainage.

**Materials and Methods**

Investigations of the drainage water quality were carried out in a livestock company field fertilized with manure in 2008–2012. Drained areas, where the drainage water is drained through outlets, Dr.1 and Dr.2 (Fig. 1), were selected for investigations.

The soil of the research subject is sandy loam. In the layer 0-40 cm of the fertilized area, the humus content in the soil fluctuated from low (1.2 %) to high (4.9 %). The content of mineral nitrogen fluctuated from 14.2 to 289 kg ha\(^{-1}\) what corresponded to the nitrogen content I (very low) and V (very high) respectively. The content of humus in non-fertilized soil fluctuated from the very low value (1 %) to moderate value (3 %). The content of mineral nitrogen fluctuated from 10.9 to 130 kg ha\(^{-1}\), what corresponded to the nitrogen content I (very low) and V (very high) (Mažvila, 1998).

For the purpose of chemical investigations, water samples from drainage were taken once per month. Water analyses were carried out by the accredited Chemical Analytical Laboratory of the Water Management Engineering Institute of Aleksandras Stulginskis University according to methods specified in the literature (Unifikuoti…, 1994). 

\(N_{total}\) was determined by applying the spectrometric method, by mineralizing with potassium persulphate.

Soil samples for agrochemical investigations were taken monthly from the depth of 0-60 cm at every 20 cm. To identify the content of nitrogen in the soil, the following research methods were applied: ammonium nitrogen (\(N-NH_4^+\)) – colorimetric with Nessler’s reagent in KCl extract; nitrate nitrogen (\(N-NO_3^-\)) – potentiometric with selective electrode. Analyses of \(N-NH_4^+\) and \(N-NO_3^-\) were carried out by means of analyser “FIA Star 5012”.

![Figure 1. Scheme of study object. Dr.1, Dr.2 – drainage outlets, D1, D2 – soil sampling places](image)

To fertilize the research fields, litter-free manure of cattle was used, and the fertilization took place in spring. The composition of manure was identified from one extract prepared by burning with concentrated sulphuric acid (\(H_2SO_4\)) and selenium (Se) catalyst. Nitrogen was identified using Kjeldal method by mineralizing with a mineralizer “Digestor 2006” as well as distilling with a distiller “Kjeltac System 1002 Distilling Unit”. According to the fertilizing value of manure, the following contents of total nitrogen passed into manure-fertilized fields in each year: 2008 – 169 kg ha\(^{-1}\), 2009 - 168 kg ha\(^{-1}\); 2010 - 169 kg ha\(^{-1}\), 2011 – 169 kg ha\(^{-1}\), 2012 – 170 kg ha\(^{-1}\). Maize for cattle forage was grown in experimental fields. To determine the rainfall and air temperature, data from Dotnuva Meteorology Station were used.

**Results and Discussion**

The results of five-year research show that higher precipitation than the climate standard was in June (34 %), July (47 %), August (24 %), December (18 %), January (32 %), and October (46 %). In April (20 %), May (27 %), and September (17 %) precipitation was lower than climate standards, while in February, March, and November the precipitation level corresponded to the climate standard.
During the observation period, the weather temperature was usually higher than climate standard, except during February, May, June, and December months. The biggest deviation from the standard climate norm was observed during April and July months +2.6 °C and 2.3 °C, respectively (Fig. 2).

The accumulation of mineral nitrogen in the soil was influenced by the favourable meteorology (\( r = 0.38, t_{\text{theor}}^{95\%} = 2.0 < t_{\text{act.}} \)). It was ascertained by means of partial correlation analysis that the lower rainfall (\( r = -0.22 \)) and the higher air temperature (\( r = 0.37 \)) conditioned the higher nitrogen concentrations in the soil fertilized with manure. The similar impact of the meteorology was observed on the concentration of nitrogen content in the non-fertilized soil (\( r = 0.35, t_{\text{theor}}^{95\%} = 2.0 < t_{\text{act.}} \)). In this variant also, the lower rainfall (\( r = -0.27 \)) and the higher air temperature (\( r = 0.33 \)) have raised the content of nitrogen in the soil.

During the research period, the highest concentrations of \( N_{\text{total}} \) were observed in the field fertilized with manure in 2008. The average annual concentration of \( N_{\text{total}} \) was 21.4 mg l\(^{-1}\). In the non-fertilized field, the highest concentration was also observed in 2008, i.e. 11.1 mg l\(^{-1}\) (Table 1).
It is specified in the literature that agricultural plants cultivated exert influence on the wash up of some other nutrients from the soil (Kinderis, 1991). The least quantities of nitrates are washed up from perennial grass areas (1.4-3.7 kg ha\(^{-1}\)) and the highest quantities – from bean and maize areas (6.8-11.5 kg ha\(^{-1}\)). The factor that maize was grown in both research versions could have conditioned higher concentrations of research chemical elements.

Researches point out that concentrations of mineral nitrogen in drainage water highly depend on the crop rotation, crop harvest and fertilization with nitrogen. The highest concentrations of mineral nitrogen in drainage water (13.1 – 13.9 mg l\(^{-1}\)) were observed in cultivation of cereal and cultivated crop. The least concentration of mineral nitrogen was obtained in grass rotation (9.6 mg l\(^{-1}\)), and by applying the rotations of cereal and cultivated crop, concentrations increased by 19 and 26 % (Aksomaitienė et al., 2007; Aksomaitienė et al., 2003).

It was ascertained by means of correlation analysis that concentrations of N\(_{\text{total}}\) in drainage water were raised by the content of mineral nitrogen in the soil during autumn and winter, and vice versa; during spring and summer, concentrations have decreased, since the best part of mineral nitrogen was used to grow the green-mass of cultivated plants (Table 1).

### Table 1. \(N_{\text{total}}\) concentration fluctuation in drainage water in seasons, mg l\(^{-1}\)

<table>
<thead>
<tr>
<th>Year</th>
<th>spring</th>
<th>summer</th>
<th>autumn</th>
<th>winter</th>
<th>Average per year</th>
<th>Standard deviation</th>
<th>Variation coefficient, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fertilized</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2008</td>
<td>20.9</td>
<td>-</td>
<td>23.5</td>
<td>20.5</td>
<td>21.4</td>
<td>1.4</td>
<td>7</td>
</tr>
<tr>
<td>2009</td>
<td>14.2</td>
<td>17.7</td>
<td>10.1</td>
<td>8.4</td>
<td>13.3</td>
<td>5</td>
<td>38</td>
</tr>
<tr>
<td>2010</td>
<td>7.6</td>
<td>6.6</td>
<td>7.8</td>
<td>5.8</td>
<td>6.9</td>
<td>1</td>
<td>15</td>
</tr>
<tr>
<td>2011</td>
<td>6.5</td>
<td>6.7</td>
<td>6.0</td>
<td>11.9</td>
<td>6.7</td>
<td>1.4</td>
<td>34</td>
</tr>
<tr>
<td>2012</td>
<td>11.6</td>
<td>14.9</td>
<td>8.6</td>
<td>11.5</td>
<td>11.7</td>
<td>2.6</td>
<td>22</td>
</tr>
<tr>
<td>Non-fertilized</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2008</td>
<td>10.6</td>
<td>-</td>
<td>11.2</td>
<td>12.5</td>
<td>11.1</td>
<td>4.8</td>
<td>43</td>
</tr>
<tr>
<td>2009</td>
<td>12.2</td>
<td>13.9</td>
<td>6.5</td>
<td>5.5</td>
<td>10.5</td>
<td>4.0</td>
<td>38</td>
</tr>
<tr>
<td>2010</td>
<td>4.6</td>
<td>4.9</td>
<td>4.8</td>
<td>5.4</td>
<td>4.9</td>
<td>1.7</td>
<td>34</td>
</tr>
<tr>
<td>2011</td>
<td>3.5</td>
<td>-</td>
<td>-</td>
<td>3.9</td>
<td>3.6</td>
<td>0.3</td>
<td>9</td>
</tr>
<tr>
<td>2012</td>
<td>3.6</td>
<td>3.2</td>
<td>3.9</td>
<td>3.8</td>
<td>3.6</td>
<td>0.3</td>
<td>8</td>
</tr>
</tbody>
</table>

The values of correlation rates demonstrate that the correlation in fertilized area is moderate; in non-fertilized area, it is weak in winter and spring and strong in summer and autumn. In the fertilized area, during the spring and summer season, the reverse correlation was identified between the research parameters: the more mineral nitrogen is accumulated in the soil the less concentration of N\(_{\text{total}}\) is observed in drainage water. Whereas, it was obtained during the autumn and winter season that great accumulations of mineral nitrogen in the soil raise the concentration of N\(_{\text{total}}\) in drainage water. It could be explained by that in spring and summer, mineral nitrogen is used by plants, and in autumn and winter, when the harvest has been stored up, the content of mineral nitrogen is washed up from the soil into drainage.

In the non-fertilized experimental field, during each season, inversely proportional correlations were identified between the content of mineral nitrogen in the soil and concentrations of N\(_{\text{total}}\) in drainage water. It could be explained by that the whole content of mineral nitrogen accumulated in the soil was used by plants; therefore, low concentrations of N\(_{\text{total}}\) in drainage water were identified.
Conclusions

Large livestock company fields fertilized annually with manure have raised the contents of $N_{\text{min}}$ in the soil, and concentrations in the soil fertilized with manure were higher by 1.5 times respectively in comparison to the non-fertilized soil.

The higher content of $N_{\text{min}}$ both in manure-fertilized soil and non-fertilized soil was conditioned by the lower rainfall and the higher air temperature.

The correlation analysis has demonstrated that concentrations of $N_{\text{total}}$ in drainage water increased due to the content of $N_{\text{min}}$ in the soil in autumn and winter, and inverse - decreased in spring and summer, as the best part of $N_{\text{min}}$ was used to grow the green-mass of cultivated plants.

References


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Genetic Differentiation of Field and Forest Ecotypes of Roe Deer (Capreolus capreolus L.) in Lithuania Based on DNA Markers

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1Aleksandras Stulginskis University, Lithuania
2Hedmark University College, Norway

Abstract

The objective of our study was to assess the genetic differentiation between the two hypothesized forest-field ecotypes of Roe deer in Lithuania by the aid of five nuclear microsatellite DNR markers. A total of 79 roe deer individuals were sampled covering parts of Lithuania, and assigned as geographical replicates of the two ecotypes based on the location they were culled. However, the AMOVA revealed no significant genetic differentiation between the field and forest ecotypes (Rst=0, n.s.; Fst=0.009, n.s.). Furthermore, no marked differences in genetic diversity parameters such as heterozygosity and allelic richness were observed. Only a slight difference in the mean number of private alleles was observed with 2,4 and 1,4 for forest and field ecotypes, respectively. We conclude that the most likely reasons for low genetic differentiation between the field and forest ecotypes in Lithuania are genome sharing between the two ecotypes via mating or common recent genetic background. Thus, the putative adaptive differentiation of Roe deer into the two ecotype habitats may suggest that forest and field ecotypes are formed due to their living environments, implying that phenotypic plasticity may be important.

Keywords: SSR, microsatellite, neutral variation, game management, genetic diversity

Introduction

Roe deer is the most numerous large wild herbivore in Europe and it is one of the most common big game species in Lithuania (Baleišis et al 1989). Here, the total Roe deer population has been estimated to be more than 109,000 individuals (2012 census report by the Environmental Ministry of Lithuania). Apparently, the most preferable habitats of Roe deer seems to be a mosaic of forests and agricultural fields where it can find both food and shelter (Brzuski et al. 1998). In Lithuania as in many European countries two Roe deer ecotypes can be distinguished: “forest” Roe deer and “field” Roe deer. This field ecotype seems to differ from the forest ecotype in morphological, morphometric and socio-ecologic traits (Pėtelis 1998, Narauskaitė et al 2011). The roe deer field ecotype is often recognized as an ecological adaptive form of a species that live in an open agricultural landscape (Kaluzinski 1982), while the forest ecotype represents the ancestral state. The landscape features of Lithuania vary in forest and field mosaic prevalence, being differently distributed.

In Southwest Lithuania the field ecotype has formed in flatlands with rich soils and low forest coverage (about 9%). It has been hypothesized that the field ecotype started to appear during 1965-1967 when then the Roe deer population abundance was at its highest in the country (Pėtelis 1998). Baleišis et al (1989) suggested that the field ecotype in Lithuania formed in the open landscape with rich soils, with a subsequent rapid increase in population density. Moreover, competition with the red deer Cervus elaphus and fallow deer Dama dama has apparently displaced the Roe deer from parts of the forest in Lithuania (Baleišis et al 1989, Petelis & Brazaitis 2003). It seems reasonable to expect that the landscape change and resource competition have influenced both population size and formation of the field ecotype in parts of Lithuania.

Genetic nuclear bi-parental markers, such as the highly variable microsatellites can provide a picture of population subdivision (Goldstein and Schlötterer 2002). Moreover, the high information content of microsatellite loci can be used on a finer scale to assess the genetic relationship among closely related populations and individuals, (Lorenzini et al 2003). Our goal was to test if the field ecotype has arisen repeatedly as a genetically divergent and derived population from the ancestral forest roe deer or if the ecotypes rather comprises two ancestral genetic lineages.

Methods

A total of 79 Roe deer muscle tissue samples were taken from four different forest bio-climatic regions in Lithuania during the 2010-2012 hunting seasons and stored in the freezer at -70°C. 38 individuals of field ecotype and 38 individuals of forest ecotypes were sampled. The ecotypes were identified based on culling location. Culling location criteria for the field ecotype: open land; woodedness of area within 3 km radius from the culling is less than 20 %, large continuous forest tracts (> 1000 ha) located not closer than 3 km away. Between 10-30 mg muscle tissue was used for DNA-extraction by adding 180 μm Genomic Digestion Buffer and 20 μg Proteinase K. The solution was stored in a heating block for 3 hours at 55°C, and centrifuged at 3 min at maximum speed. Then 20 μg of RNase A and 200 μg of Lysis Binding buffer were added, and vortexed. Finally, 200 μg of 70°C ethanol was added to precipitate DNA. For DNA purification, the prepared lysate was added to a micro-tube and centrifuged at maximum speed. Washing buffer 1 was added to the micro-tube and centrifuged at maximum speed, repeating the procedure with Washing buffer 2. After washing, 100 μg of the Elution buffer was added and centrifuged for 1 min at maximum speed. Following checking the concentration of the purified DNA, it was stored in a freezer at -20°C. A set of five primer pairs were used (developed for reindeer by Roed and Midtjylland (1998), for roe deer by Postma et al, (2001) and by Lorenzini et al. (2003)): NVHRT30, NVHRT71, NVHRT48, NVHRT16 and NVHRT24. We combined the five microsatellites into two multiplex reactions for PCR amplification – NVHRT30 and NVHRT71 were pulled together in multiplex No 1, as well as NVHRT48, NVHRT16 and NVHRT24 microsatellites were pulled together in multiplex No 2. After the
electrophoresis, allele sizing was performed using the GeneMapper program (Applied Biosystems version 4.0). An
AMOVA based on Rst and Fst fixation indexes was used to estimate genetic differences between the two putative
ecotypes in GenAlEx V6.1 (Peakall and Smouse 2006). The following set of genetic diversity parameters, recorded in
GenAlEx V6.1, were calculated and compared between the two putative roe deer ecotypes:

- **Na** = No. of Different Alleles
- **Ne** = No. of Effective Alleles = 1 / (Sum pi^2)
- **I** = Shannon’s Information Index = -1 * Sum (pi * Ln (pi))
- **Ho** = Observed Heterozygosity = No. of Heterozygotes / N
- **He** = Expected Heterozygosity = 1 - Sum pi^2
- **UHe** = Unbiased Expected Heterozygosity = (2N / (2N-1)) * He
- **F** = Fixation Index = (He - Ho) / He = I - (Ho / He)
- Where pi is the frequency of the ith allele for the population and the Sum pi^2 is the sum of the squared
  population allele frequencies.

![Figure 1](image)

**Figure 1.** The locations of the sampled forest and field roe deer ecotypes with lines defining eco-climatic zones (given in the figure)

**Results and discussion**

The studied loci were informative with 3 to 11 alleles, where the lowest number of alleles was observed for
locus NVHRT30 (3 alleles) and the highest – at loci NVHRT16 and NVHRT24 (both with 11 alleles). Most of the
individuals were heterozygous with a mean observed multilocus heterozygosity of 0.81. This could be able to indicate a
sufficient variation and discrimination power of the 5 loci to detect the genetic differences between the field and forest
ecotypes.

The AMOVA based on the Rst fixation index revealed no significant differences between the forest and field
ecotypes (Rst=-0.009, p=0.7, Table 1). Most of the variation was attributable to the partition among-individuals within
ecotypes (95%) and within individuals (5%). A similar result was obtained using the Fst index, which does not consider
the variance in the repeat size of microsatellites revealing no among ecotype differentiation (0%) and high among
individual variation (100%) (Fst=0.04 p=0.35, Table 2). AMOVAS based on the Fst fixation index for each of the 5 loci
separately showed that the locus NVHRT71 returned the highest Fst value (0.02) while Fst for the rest of the loci varied
at about 0.002. Thus, the locus N71 is the most useful in revealing genetic differences among the ecotypes.
Table 1. The results of AMOV A based on the Rst fixation index

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>SS</th>
<th>MS</th>
<th>Est. Var.</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Among Populations</td>
<td>1</td>
<td>6425.31</td>
<td>6425.31</td>
<td>0.0</td>
<td>0%</td>
</tr>
<tr>
<td>Among Individuals</td>
<td>77</td>
<td>775666.78</td>
<td>10073.59</td>
<td>4914.58</td>
<td>95%</td>
</tr>
<tr>
<td>Within Individuals</td>
<td>79</td>
<td>19310.50</td>
<td>244.44</td>
<td>244.44</td>
<td>5%</td>
</tr>
<tr>
<td>Total</td>
<td>157</td>
<td>801402.58</td>
<td>5159.02</td>
<td>100%</td>
<td></td>
</tr>
</tbody>
</table>

Table 2. The results of AMOV A based on the Fst fixation index

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>SS</th>
<th>MS</th>
<th>Est. Var.</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Among Populations</td>
<td>1</td>
<td>3.72</td>
<td>3.72</td>
<td>0.01</td>
<td>0%</td>
</tr>
<tr>
<td>Within Pops</td>
<td>77</td>
<td>246.28</td>
<td>3.20</td>
<td>3.20</td>
<td>100%</td>
</tr>
<tr>
<td>Total</td>
<td>78</td>
<td>250.00</td>
<td>3.21</td>
<td>100%</td>
<td></td>
</tr>
</tbody>
</table>

There were no marked differences between the ecotypes in the genetic diversity indexes (Fig. 1). However, there was a tendency for a greater genetic diversity of the field ecotype: higher number of alleles and slightly higher observed heterozygosity, the other parameters including the expected heterozygosity were rather uniform and conforming to the values obtained at original study where the primers were developed (Roed and Midthjell 1998, Buntjer et al. 1998) (Table 3, Fig. 1, 2). The expected heterozygosity was similar to a study of 2 Roe deer populations in Holland (He ca. 0.5, Postma et al. 2001). The genetic diversity indexes were comparably high, indicating that the Roe deer populations are not isolated and it seems to no threats for inbreeding depression in the populations studied. For loci NVHRT16 and NVHRT48, the observed heterozygosity was higher for the field ecotype, but for locus NVHRT71 vice versa (Fig. 2). The field ecotype also had more private alleles (mean of 2.4 versus 1.4 in the forest ecotype). In spite of observations on rather localized habitats, Roe deer is known for the ability to travel over large distances (Danilken and Hewison 1996). An interpretation of this slightly greater diversity of the field ecotype could be due to the most likely larger habitats and the migration distances of the field ecotype where the possibility for mating with more distant and genetically different individuals is greater than for the forest ecotype that usually does not migrate out of the own forest tract (Danilken and Hewison 1996). This result provides a genetic indication for lower migration in the forest ecotype compared to the field ecotype.

The allelic frequency analysis for each locus also showed close genetic affinity between the ecotypes (not shown). An exception was the locus NVHRT16, for which the field ecotype possessed more private alleles and a higher allelic richness (Fig. 3). We also examined in a greater detail the allelic variation in the locus showing the greatest ecotype differentiation (Fig. 4). It is evident from figure 4 that the field genotype had a markedly greater proportion of the 105 bp allele.

Figure 2. Allelic patterns across the roe deer ecotypes. Na = No. of Different Alleles. Na (Freq >= 5%) = No. of Different Alleles with a Frequency >= 5%. Ne = No. of Effective Alleles = 1 / (Sum pi^2). I = Shannon's Information Index = -1* Sum (pi * Ln (pi)). No. Private Alleles = No. of Alleles Unique to a Single Population. No. LComm Alleles (<=25%) = No. of Locally Common Alleles (Freq. >= 5%) Found in 25% or Fewer Populations. No. LComm Alleles (<=50%) = No. of Locally Common Alleles (Freq. >= 5%) Found in 50% or Fewer Populations. He = Expected Heterozygosity = 1 - Sum pi^2.
Figure 3. Observed heterozygosity for the roe deer ecotypes ordered by microsatellite locus

Table 3. Genetic diversity indexes for each locus compared between roe deer ecotypes

<table>
<thead>
<tr>
<th>Ecotypes</th>
<th>NVHRT30</th>
<th>NVHRT 71</th>
<th>NVHRT 48</th>
<th>NVHRT 16</th>
<th>NVHRT 24</th>
</tr>
</thead>
<tbody>
<tr>
<td>Field</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>38</td>
<td>38</td>
<td>35</td>
<td>35</td>
<td>34</td>
</tr>
<tr>
<td>Na</td>
<td>3</td>
<td>5</td>
<td>6</td>
<td>11</td>
<td>9</td>
</tr>
<tr>
<td>Ne</td>
<td>2.050</td>
<td>2.429</td>
<td>3.746</td>
<td>4.949</td>
<td>2.636</td>
</tr>
<tr>
<td>I</td>
<td>0.753</td>
<td>1.094</td>
<td>1.432</td>
<td>1.856</td>
<td>1.242</td>
</tr>
<tr>
<td>Ho</td>
<td>0.921</td>
<td>0.632</td>
<td>0.829</td>
<td>0.743</td>
<td>0.941</td>
</tr>
<tr>
<td>He</td>
<td>0.512</td>
<td>0.588</td>
<td>0.733</td>
<td>0.798</td>
<td>0.621</td>
</tr>
<tr>
<td>UHe</td>
<td>0.519</td>
<td>0.596</td>
<td>0.744</td>
<td>0.810</td>
<td>0.630</td>
</tr>
<tr>
<td>F</td>
<td>-0.799</td>
<td>-0.074</td>
<td>-0.130</td>
<td>0.069</td>
<td>-0.516</td>
</tr>
<tr>
<td>Forest</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>38</td>
<td>40</td>
<td>38</td>
<td>38</td>
<td>38</td>
</tr>
<tr>
<td>Na</td>
<td>2</td>
<td>9</td>
<td>7</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>Ne</td>
<td>1.988</td>
<td>3.628</td>
<td>3.646</td>
<td>3.765</td>
<td>2.475</td>
</tr>
<tr>
<td>I</td>
<td>0.690</td>
<td>1.555</td>
<td>1.463</td>
<td>1.438</td>
<td>1.084</td>
</tr>
<tr>
<td>Ho</td>
<td>0.921</td>
<td>0.850</td>
<td>0.605</td>
<td>0.500</td>
<td>1.000</td>
</tr>
<tr>
<td>He</td>
<td>0.497</td>
<td>0.724</td>
<td>0.726</td>
<td>0.734</td>
<td>0.596</td>
</tr>
<tr>
<td>UHe</td>
<td>0.504</td>
<td>0.734</td>
<td>0.735</td>
<td>0.744</td>
<td>0.604</td>
</tr>
<tr>
<td>F</td>
<td>-0.854</td>
<td>-0.173</td>
<td>0.166</td>
<td>0.319</td>
<td>-0.678</td>
</tr>
</tbody>
</table>

Table 4. Comparison of multilocus genetic diversity parameters between the roe deer ecotypes

<table>
<thead>
<tr>
<th>Ecotypes</th>
<th>N</th>
<th>Na</th>
<th>Ne</th>
<th>I</th>
<th>Ho</th>
<th>He</th>
<th>UHe</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Field</td>
<td>Mean</td>
<td>36.000</td>
<td>6.800</td>
<td>3.162</td>
<td>1.275</td>
<td>0.813</td>
<td>0.650</td>
<td>0.660</td>
</tr>
<tr>
<td></td>
<td>SE</td>
<td>0.837</td>
<td>1.428</td>
<td>0.529</td>
<td>0.183</td>
<td>0.058</td>
<td>0.051</td>
<td>0.052</td>
</tr>
<tr>
<td>Forest</td>
<td>Mean</td>
<td>38.400</td>
<td>5.800</td>
<td>3.100</td>
<td>1.246</td>
<td>0.775</td>
<td>0.655</td>
<td>0.664</td>
</tr>
<tr>
<td></td>
<td>SE</td>
<td>0.400</td>
<td>1.158</td>
<td>0.364</td>
<td>0.160</td>
<td>0.095</td>
<td>0.047</td>
<td>0.048</td>
</tr>
</tbody>
</table>
Figure 4. Allele frequencies at locus NVHRT16 showing greater allelic richness of the field ecotype than the forest ecotype

Figure 5. Allelic frequency at locus NVHRT71 for roe deer ecotypes showing the greatest differentiation between the two ecotypes

Conclusion

Our data indicates only minor and nonsignificant genetic differentiation between the field and forest ecotype at the analysed microsatellite loci. A possible interpretation here is a common ancestry of the two ecotypes (MÖRSCH & LEIBENGUTH (1994) and/or genome sharing between the two ecotypes via mating. Thus, we deny the prediction of comprises of two ancestral genetic lineages for ecotypes formation. However, there was a slight tendency for a higher
genetic diversity of the field ecotype (especially allelic richness and observed heterozygosity). We interpret this higher diversity of the field ecotype as a consequence of likely larger habitats for the field ecotype than for the forest ecotype. But no evidence for two different ancestral genetic lineages was found based nuclear microsatellites.

Acknowledgement. This project was partly supported by project “Promotion of Student Scientific Activities” (VP1-3.1-ŠMM-01-V-02-003) from the Research Council of Lithuania (G.N.). This project is funded by the Republic of Lithuania and the European Social Fund under the 2007 – 2013 Human Recourses Development Operational Program’s priority 3.

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Impact of Different Soil Tillage Intensity on Soil Water Erosion in Spring Time

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Czech University of Life Sciences Prague, Czech Republic

Abstract

The paper focuses on evaluation of methods of establishing the corn crop and oat crop in terms of resistance to water erosion between years 2010-2012. Field trial was established for measurement on land with an average slope of 5.4° in year 2009. The field with light soil is located in the area in central Bohemia at an altitude of 420 m. The field trial consists of seven variants based crop corn and spring cereals. Using the method retention microplots were evaluated by surface runoff and soil washes off during intense rains during the sowing of crops. The results confirm the importance of soil conservation technologies of soil tillage and sowing of corn to reduce the risk of land degradation by water erosion. There were also confirmed the positive impact cover crop soil cover in the space between corn rows.

Key words: soil tillage; surface runoff; erosive wash, corn production

Introduction

Erosion due to human activity is a problem also because it is much faster than the process of soil formation. Loss of organic matter and associated biological activity causes adverse impacts on the physical properties for crop growth, reducing porosity and increasing bulk density. Types of erosion processes are more, but in agricultural soils is most evident water and wind erosion (Morgan, 2005). The Czech Republic is characterized by a high average gradient of all agricultural land. Tippl, Janeček and Bohuslavék (2010) reports, that more than 53 % of agricultural land in the Czech Republic is situated on slopes greater than 3°. The high average gradient, combined with light soil and expanding wide-row crops (corn) are at increased risk of water erosion. Corn growing area due to the construction of new biogas plants in Czech Republic.

Very often are described beneficial effects of soil conservation technologies to reduce water erosion. The main principle of this technology is the use of organic matter (harvest crop residues, biomass intercrops) on the surface of the soil. Organic matter partly covers the surface of soil and reduces surface runoff and erosive wash away. It also can be used for integration of vegetation surface. For soil conservation tillage is essentially a reduced tillage by reducing the number of operations, merging them while protecting the surface of soil plant residues.

Soil conservation tillage can increase the capacity of the hydraulic conductivity of the soil and thus followed by water infiltration into the soil. For this reason it can contribute to reduce the surface water runoff and erosion risks. On the other side conventional tillage creates homogeneous soil layer, which can reduce water infiltration into the soil (Titi, 2002). Shipitalo et al. (2000) also confirmed that soil conservation technologies can reduce surface runoff and increase water infiltration into the soil.

Water erosion is difficult to follow. Relatively accurately determine the surface runoff during intense rainfall and soil washed down the weight by using runoff on micro plots (Janeček et al., 2005). Bagarello and Ferro (2007) reported the use of drainage of micro plots with different surface at the experimental station Sparacia in Sicily. This station is used to drain the microplots areas from 0.04 m² to 4 m² and then drain micro plots from 11 m² to 352 m². On small micro plots captures all the runoff is washing away soil, with larger plots be accounted for part of the volume of surface runoff, using the reducers

Materials and methods

The field trial was established on the light cambisol with an average slope of 5.4 °. The plot is located in the area Nesperká Lhota in central Bohemia at an altitude of 420 m. The field trial consists of seven variants. Plot of land for each variant is 6m x 50 m in length side is facing the fall line.

After harvesting of triticale (crush straw) was the site of the second half of August 2009 followed shallow tillage with disc tiller. In options 4, 5, 6 remained on the ground in autumn, without further processing, for options 1, 2. Three followed options in October 2009 unilaterally plow tillage to a depth of 0.2 m (driving in the direction of contour sets, tilting to hunk slope). Tillage and seeding in the spring as indicated in each experiment variants. The field trial is repeated for several years since 2009. Tillage and seeding is repeated for each variant of each year.

Variants of experiment:
1. Conventional tillage technology for corn - plowing in the fall, winter left rough wake, spring sowing soil preparation with harrow, seed corn.
2. Variant of tillage, spring cereals - plowing in the fall, winter left rough wake, spring sowing soil preparation with harrow, sowing oats.
3. Variant of tillage, corn trade intercrop (winter cereal crop sown in spring) - plowing in the fall, winter left rough wake, spring sowing soil preparation with harrow, triticale seeding, sowing corn.
4. Option no tillage, corn free trade intercrop with spring sowing soil preparation - plowing the previous crop harvest disc tiller, spring tillage tine cultivator to a depth of 0.10 m, sowing corn.
5. Option no tillage, spring cereals - plowing after harvest crop, sown in spring oats.
6. Option no tillage, corn free trade intercrop without spring sowing soil preparation - plowing the previous crop harvest disc tiller in autumn.

7. The "black fallow" - in the fall plowing, left rough over the winter wake, spring tillage tine cultivator to a depth of 0.15 m is maintained without vegetation - 5 non-selective herbicide applications (Roundup Rapid, 4 l ha⁻¹).

For each variant experiment after sowing corn and oats were installed 4 microplots for measurement. Area of each microplot is defined by walls of sheet metal height 0,12 m. The collector is located at the bottom of each microplots. It transports water into the plastic container, which is buried below the catching microplots. Area of each microplots is 0,4 m x 0,4 m.

To measure the size and intensity of precipitation is located weather station Vantage Vue near the experiment. Measurement of surface runoff followed ever after intense rainfall. Surface runoff was detected by measuring the volume, the amount of soil washed by filtering runoff and subsequent soil drying at 105°C and weighing the soil on a laboratory scale.

Results and discussion

Values of surface water runoff and erosion wash during events between May 2010 - 2012 are shown in the graphs in Figure 2 to 4. Table 1 shows the rainfall in the period. Data were obtained from the weather station Vantage Vue near the field experiment.

Table 1. Rainfall in period

<table>
<thead>
<tr>
<th>Month/Year</th>
<th>Rain (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>May 2010</td>
<td>72.8</td>
</tr>
<tr>
<td>May 2011</td>
<td>65.8</td>
</tr>
<tr>
<td>May 2012</td>
<td>68.8</td>
</tr>
</tbody>
</table>
Rainfall during May 2010 represented a 72.8 mm. It was the rain with very low intensity, so there was a high water infiltration into the soil. Increased runoff was recorded in the second part of this period when saturated soil water. The graphs in Figure 2 shows that the erosion of this first event was recorded, while the highest surface runoff rainwater to variants 1, 2, 3 and 7 (variant with plowing). Soil which was washed off in these variants is high. The highest erosive wash was found in variants 1 and 7 - conventional tillage technology for corn and conventional tillage in maintaining soil without vegetation (black fallow). Weight of erosive wash difference between variants 1 and 7 was below statistical significance. Between these two variants and other variants of the field trial the difference was statistically significant.

In May 2011, there were two slow and one short rain storm with medium intensity. Rainfall reached 68.8 mm. A significantly high surface runoff was observed in variant No. 1,3 and 7. Erosive wash in variant No. 7 was significantly higher than for all other variants. Was also statistically significantly higher weight of erosive wash in variant No. 1 (conventional tillage technology for corn). This measurement confirms the assumptions identified during the first year of measurement. Results from the control variant (variant 7) show a high risk of soil washed off the bare soil especially in storms with intense rainfall.
Figure 4. **Monitored parameters in storm with medium intensity in May 2011**

Figure 4 is a detailed view of erosion events of May 2011. It was a medium intensity storm. It shows a positive effect of organic matter covering the soil surface on both monitored parameters. Graphs show significant differences especially in variants 1 and 7. Statistically significant differences were determined by Tukey HSD test (Fig. 5).

![Graph showing monitored parameters in storm with medium intensity in May 2011](image)

<table>
<thead>
<tr>
<th>Variant</th>
<th>Surface runoff/average 1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>2.44</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>2.50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>2.64</td>
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<tr>
<td>2</td>
<td>3.46</td>
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</tr>
<tr>
<td>1</td>
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</tr>
<tr>
<td>3</td>
<td>4.23</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>4.54</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Tukey HSD, alfa = .05000**

<table>
<thead>
<tr>
<th>Variant</th>
<th>Erosive wash/average 1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>4.20750</td>
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<td>4</td>
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<td>1</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>9.34750</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 5. **Tukey HSD test for both parameters**

In May 2012, there were three short storms with low intensity. Rainfall reached 65.8 mm during May 2012. Statistically significant low surface runoff was observed in variants No. 4, 5, 6. Soil washed off with this option was low. Weight of erosive wash in variant No. 7 was significantly higher than for all other variants. Was also statistically significantly higher weight of erosive wash in variant No. 1 (conventional tillage technology for corn) than in variant No. 2 to 6. This measurement demonstrates the risk of uncovered soil with organic matter during intense rainfall.

When comparing the measured values with the results of authors who have dealt with the quantification of erosion processes in the application of different tillage practices in the production technology, were confirmed positive protective effect of plant biomass in the soil surface and the surface layer of soil (Truman et al., 2005, Rasmussen,
1999, Azooz, Arshad, 1999). Even under the conditions of the field experiment showed that the cultivation of corn using conventional tillage technology with tillage is risky, alternative technology of corn cultivation without tillage showed significantly less erosion with the erosion events.

Conclusion

In measuring the erosion events caused by rain associated with storm activity showed an increased risk of soil water erosion in the cultivation of corn using conventional tillage technology with plowing. Measurements in this paper include data from the month of May. In the period immediately after sowing corn land is very susceptible to water erosion. This is because of the absence of the plants grown on the surface. For this reason, it is advisable to use biomass crops or crop residues to increase the resistance of soil to water erosion. Due to the growing need of organic matter for biogas plants across the EU, these issues will take on greater importance. It is advisable further research, particularly with regard to the behavior of different types of soils.

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References


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Functional Zoning and Recreational Load-bearing Capacity of Dubysa Regional Park

Gediminas Palekas
Aleksandras Stulginskis University, Lithuania

Abstract
A particular importance to protected areas provides the exact functional zoning. It is division of the territory into sustainable, preservative, recreational, economic, living areas, where different modes of protection and usage exist. However, these zones are not consistently defined in all regional parks. The possibility of a complete separation of the zones from each other is theoretical, but in practice it is very difficult to perform. It is also difficult to apply in practice the minimization of forestry, farming and other economic activities, in order to enrich biological diversity. An analysis shows that the most valuable natural areas of Dubysa Regional Park do not fall into any of the protected areas.

Recreational use of the territory is one of the most important functions of regional parks. They domesticated the landscape values of the priority objectives should be allocated to the cognitive tourism. Therefore, the establishment of regional parks is associated with the natural cultural and regional interest in the preservation of landscapes and valuable ecosystems. Commercial and recreational use areas should be kept under control.

Introduction
The system of protected areas in the Republic of Lithuania is based on the maintenance of landscape ecological balance, biodiversity and preservation of the genetic fund, renewal of natural resources, protection of natural and cultural heritage. It also provides all conditions under which scientific and cognitive research is performed and recreation is developed.

By developing industry and energy, forests and agriculture, cities and towns, humanity loses natural areas and cultural heritage. In creating the system of protected areas, Lithuania chose an integrated way and has been purposefully moving on it for more than five decades. Since 1992 we can state that we have no united protected areas, not even a network of protected areas, but scientifically sound system of protected areas. Lithuanian system of protected areas is characterized by diversity, representativeness, complexity of coverage, evenness, connectivity and flexibility (Baškytė et al., 2006).

Combining the territory of all types of active rural ecology into a Land Management System, it is possible to manage compensation functions of the landscape and ensure its structural stability. Each conservation area has its own values, covering natural and cultural heritage (Rosengren, Franzen, 2007).

Protected areas are an integral part of the system of recreational areas. Most of the regional parks or their parts fall into singled out recreational touring areas, in which recreational function is as important as the environmental one. In regional parks recreation should be developed more than in the national ones, especially by local residents. Greater variety of recreation can be attained in separate types of reserves. The most favorable conditions for the cognitive, commercial and general tourism are in the landscape, geological, geomorphological and river reserves (Nacionalinė saugomų teritorijų vystymo strategija, 2000).

It is possible to preserve natural values in the country of virile economic activity (Lithuania can be attributed to this category as well) only by implementing specific farming programs. Of course, in the most sensitive areas of maximum environmental value economic activities should be completely banned. However, the actual area of these sites will never be sufficient to preserve all the rare and endangered species. In the majority of protected areas economic activity of people is limited, however, these restrictions must be considered taking into account the characteristics of ecosystems, peculiarities of the flora and fauna. Those restrictions are to ensure the protection of natural values, stability of ecosystem communities. Protected areas, where natural balance is already violated and processes of change within communities pose a threat to protected objects, it is necessary to carry out management work of these areas (Raudonikis, 1999).

The aim of the study - to clarify the boundaries of functional areas of the park and to assess its recreational load-bearing capacity based on the study data of Dubysa regional park. The object - functional zones of Dubysa regional park. The main objectives: 1. To analyse the features of functional zoning of Dubysa regional park and to review the boundaries of functional zones of the regional park based on botanical research. 2. To identify the condition of existing recreational areas and provide recommendations for its improvement.

Keywords: regional park, functional zoning, recreational area, load-bearing capacity.

Research methods
Analysis of phytocenotic and floristic research data was made, according to Dubysa regional park staff presented data. Was distinguished nine valuable areas near to recreational areas.

Forests in accordance with their share of recreational load are divided into mass, moderate and episodic attendance zones. Massively visited forests can be used at all ecological capacity, moderately attended forests can be allowed to degrade until digression stage I, while episodically visited forests should be protected from damage. Timely
notice of digression degree (phase II) would help to avoid irreversible processes. The boundary between qualitative change of digression processes from reversible to irreversible is called the resistance threshold of forest biogeocenose. Visually, it can be determined in accordance with external view of the forest, disappearance of the understorey.

Recreational digression was determined for each of the seven separate recreation priority areas. Some recreational areas cover a large area, thus efforts were made to select sites in places where visits are slightly more frequent, the load is higher, beside recreational facilities and so on.

Recreational digression is the impoverishment of ecosystem due to their recreational use. Four stages of digression are distinguished: relatively intact, slightly damaged, moderately and severely damaged. Recreational phase of digression is determined by the scale (Table 1).

Table 1. Guides to determine digression stage

<table>
<thead>
<tr>
<th>Evaluation indicators</th>
<th>Digression stage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area damaged to mineral soil in%</td>
<td>Area covered by the typical grass -% moss cover</td>
</tr>
<tr>
<td>&lt;1</td>
<td>&gt;95</td>
</tr>
<tr>
<td>1-5</td>
<td>94-50</td>
</tr>
<tr>
<td>6-40</td>
<td>&gt;40</td>
</tr>
<tr>
<td>&gt;40</td>
<td>Is not, or only fragments</td>
</tr>
</tbody>
</table>

Source: (Riepšas, 1990)

Area (%) trampled up to mineral soil, also covered with typical grass - moss cover is determined visually in 10 m² plots, which are set out evenly throughout the site. Sites with an area of up to 1 ha, these indices are determined in not less than 20 of such plots. When the site area is 1-3 ha, 30, and it is greater than 3 hectares - 40 of such observation plots. The amount of typical healthy undergrowth and underbrush (%) is determined in 10-20 m² plots, located evenly on the area covered with undergrowth and underbrush. When the site area is less than 1 hectare, it is necessary to use four of such plots, if the site area is 1-3 ha, 6, and when more than 3 hectares – 8 sample plots. If the area occupied by undergrowth and underbrush is less than it should be, a continuous evaluation of the undergrowth and underbrush is carried out. In the sample plots all undergrowth and underbrush plants are evaluated. Injured and called the plants that have at least one broken twig or shoot, as well as wounds on the stem or to the cambium independently of the time of appearance.

Stand stocking level is determined by comparing former stocking level, current stocking level, and taking into account peculiarities of the economic activities (whether felling of green trees was done or not). The stage of digression is determined based on all four indicators. In cases where at least one indicator shows a different phase than the others, an average from all four indicators is derived.

Distribution of functional zones in Dubysa regional park

According to natural and cultural values, their nature, forms of protection and usability, the following functional priority areas in Dubysa regional park have been distinguished: conservation (reserves), environmental protection, recreation, housing, among which conservation area occupies the largest territory - 86 percent (Figure 1).

![Distribution of functional zones in Dubysa regional park, 2013](image)

Conservation area of the regional park consists of Dubysa hydrographic, Lyduvėnai and Betygala landscape, Plauginiai botanical-zoological, Luknė and Kirkšnovė geomorphological, Palonas botanical and Pasandravys historic reserves. Ecological protection priority area consists of wooded or agricultural areas, not characterized by exceptional natural or cultural heritage values, but playing important geoeological or field protection functions. In the territory of the regional park 7 recreational priority areas were identified, with a total area of 956 hectares (Table 2).
Table 2. Recreational areas of Dubysa regional park

<table>
<thead>
<tr>
<th>Recreational zone</th>
<th>Area, ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Lyduvėnai</td>
<td>16.06</td>
</tr>
<tr>
<td>2. Kalniškiai</td>
<td>76.22</td>
</tr>
<tr>
<td>3. Padubysys</td>
<td>390.96</td>
</tr>
<tr>
<td>4. Luknė</td>
<td>115.40</td>
</tr>
<tr>
<td>5. Betygalos</td>
<td>20.48</td>
</tr>
<tr>
<td>6. Plembergas-Tvenkiniai</td>
<td>208.42</td>
</tr>
<tr>
<td>7. Bulavėnai</td>
<td>128.86</td>
</tr>
<tr>
<td>All:</td>
<td>956.44</td>
</tr>
</tbody>
</table>

Source: www.Dubysa.info

Valuable botanical areas outside the protected areas of Dubysa regional park

The location of the park is very interesting from the phytogeographic point of view: its territory stretches over 3 phytogeographic areas. According to floral-phytocenologic division of Lithuania (Natkevičaitė - Ivanauskienė, 1983) the northwestern boundary of the park falls within the northeastern Samogitian and Zemgale plains region of the northern belt. The northern part of the park - within the phytogeographic region of eastern Samogitian plateau and northern Lithuanian lowland of this belt. The rest of the park area falls within the phytogeographic region of southern Lithuania of the southern belt. For this reason, Dubysa regional park is rich in species of both northern and southern range.

Characterizing biological diversity in the areas concerned, much data is provided by the species composition of flora. One of the most characteristic indices of flora in each area is multi-systemic family spectrum (Figure 2).

Figure 2. Comparison of spontaneous flora between Dubysa Regional Park and all Lithuania

Source: compiled from the author, according to Dubysa regional park staff presented data.

Conserving biological diversity in the anthropogenic area of Dubysa regional park, it should be sought to preserve not only plant species or plant communities included into the Lithuanian Red Data Book, but also the remaining natural or herbaceous and woody vegetation components of low anthropogenic impact, which best reflect vegetation components of the regional park. It is therefore necessary to seek for complex protection of the vegetation, so that the most typical vegetation components of the regional park would occur within different protection zones (Lithuanian Red Data Book, 2010)

Analysis of phytocenotic and floristic research data suggests that the current zonation of Dubysa regional park was done regardless of the biodiversity of the park and is unfavorable for its conservation. In the territory of the regional park only one zoological reserve in Plauginiai forest has been singled out, the vegetation of which degraded due to intensive logging. The most valuable natural areas do not fall into any of the protected areas.

In the case of a new zoning scheme of Dubysa regional park, it is proposed to take into account the levels of natural vegetation in protected areas, the presence of rare flora and fauna specimens, regional representativeness and uniqueness of the vegetation (see Table 3).
Table 3. Valuable botanical areas of Dubysa regional park

<table>
<thead>
<tr>
<th>Locality</th>
<th>Protected species</th>
<th>Protected area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paltupiai</td>
<td>Isopyrum thalictroides</td>
<td>Fagetalía broad-leaved forests</td>
</tr>
<tr>
<td>Skiručai</td>
<td>Prunus spinosa; Gentiana cruciata.</td>
<td>Slopes of Dubysa</td>
</tr>
<tr>
<td>Black alder forests of Padubysys</td>
<td>Dactylorhiza longifolia</td>
<td>Festuco-Brometea erecti meadows</td>
</tr>
<tr>
<td>Kalniškiai</td>
<td>Centaurea phrygia</td>
<td>Alnetum glutinosae nemoral alders</td>
</tr>
<tr>
<td>Slopes of Plieniuskas</td>
<td>Centaurea phrygia</td>
<td>Mesobrometum erecti steppe meadows</td>
</tr>
<tr>
<td>Confluence of Tvarkantė and Antupis</td>
<td>Carex muralis; Cerastium sylvaticum; Glyceria nemoralis; Dactylorhiza ruskovii</td>
<td>Carpinion betuli slope forests</td>
</tr>
<tr>
<td>Lapišė</td>
<td>Canioselinum tataricum</td>
<td>Pruno padi – Alnetum incanae grey alder forests</td>
</tr>
<tr>
<td>Valley of Mūkė</td>
<td>Gentiana cruciata; Centaurea phrygia; Orchis mascula</td>
<td>Festuco-Brometea erecti</td>
</tr>
<tr>
<td>Kaulakiai</td>
<td>Arctium nemorosum; Canioselinum tataricum</td>
<td>Airë and Liolinga valley slopes, maple and oak forests</td>
</tr>
</tbody>
</table>

Source: compiled from the author, according to Dubysa regional park staff presented data.

Determination of recreational digression stage in Dubysa regional park

Since 1995 forest grouping was introduced. Their division into groups and categories in accordance with the prevailing functional destination and economic regime is based on legal standards, but the standards of recreational and protective forests should be improved in the future. Distribution forests into groups is based on the principle that the economic regime should not undermine biodiversity (Brukas, 1997).

In recent years, the most undesired changes in the landscape were preconditioned by the rapidly growing recreational load, technogenic invasion, urban development, as well as higher forest management intensity. Increased mobility of the population has substantially augmented recreational impact. Therefore, increases the number of damages caused to landscape, ever more forest digression spots are found due to active rest of people.

Recreation, as well as any activity that uses natural resources will inevitably affect the natural environment, changing the landscape characteristics and its individual components. The soil is compacted, natural forest litter is destroyed, waste is accumulated in recreation areas and the soil is contaminated.

Exposed to physical and chemical changes in the environment, visual expression of the landscape changes along with the emotional experience it provides. This leads to visual environmental pollution and loss of the aesthetic value of landscape (Riepšas, 2007).

Intensity of visits to a recreational area, recreational loads are revealed by grass persistence. In intensively visited places degrades not only the vegetation, but also other natural components. To solve the problems, coordination of human needs and activities in the environment is required. Therefore, it is necessary to evaluate the changing situation and to limit or even eliminate recreational loads in more sensitive, vulnerable natural areas at risk of degradation (Lankelis, 1997).

It is almost impossible to avoid smaller or larger ecosystem changes during recreation. Strolling through the forest a man tramples individual plants or their parts. If there is not much walking around, very few plants are damaged and the soil is practically uncompacted. Then only the live part of the ecosystem undergoes a little change, while the dead is only very slightly affected. Plants relatively quickly restore their damaged parts, while instead of the dead ones grow new, and often even of the same species, thus the former ecosystem manages to recover. However, if walking in the forest is massive, plants fail to recover. Weaker grass cover is unable to protect soil against compaction. Its physical and mechanical properties undergo changes. This leads to a significant change of ecotope. Thus, recreational forests are often impoverished, or even completely destroyed.

The results obtained are presented in Table 4.
As can be seen from the table, in Kalniškiai recreation area and Padubysys forest area prevails stage II (moderately damaged). Digression stage I (slightly damaged) dominates in Lyduvėnai, Luknė, Plembergas -Tvenkiniai areas. These zones are known from ancient times and are favorite resting places of indigenous people. They are close to Raseiniai, convenient transportation, with available recreational facilities. Forests in Raseiniai district are not very suitable for recreation, because they are wet, many young stands. The region is not abundant in water basins, which is also important to tourists. Therefore, several recreational areas receive a higher load.

In 2007, the staff of Raseiniai State Forest Enterprise initiated the studies on recreational benefit of forests. About 80 percent of the respondents stated that in the forest they lack well equipped recreation areas, bike trails, cognitive paths and other leisure facilities. Approximately two-thirds of those said that in the forest there is also insufficient information provision, such as signs and indications, information on cognitive and educational objects. Thus, currently the largest target groups of DRP, i.e. water tourists, cycling enthusiasts and other visitors lack information stands, banks suited for the disembarkation of canoers, camping sites equipped with toilets, electricity, outdoor furniture, summerhouses, playground facilities, changing cabins, information desks, infrastructure well adapted to the access of the disabled, parking, catering and other facilities. These facilities would help to reduce load on some of the popular places of recreation and reduce their digression.

Conclusions

The study has shown that the current zonation of Dubysa regional park must be specified. There could be distinguished nine areas valuable from botanical viewpoint. The most valuable natural areas are outside of any protected areas.

In recreational areas dominate digression stages of low and moderate damage. Most popular areas suffer from heavy recreational load. In the region there is a lack of outdoor recreation facilities. These facilities would help to reduce digression in some popular recreational areas.

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Impact of Cadastre on Economic Growth

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Abstract

Modern land administration systems support efficient land markets and effective land use management and are fundamental to prosperous society and therefore is key element addressing the current economic crisis. Therefore it is important that in the country is established land registration system what supports governance in sustainable development, provides all security of tenure and real property rights, facilitates real estate investments and transactions an ensure effective and transparent property valuation, land-use planning and sustainable land development.

Future is for demand driven cadastre development thereby is necessary to be aware what does a user need for sustainable development decisions – reliable data, full data coverage of a country, standardized data formats, easy access (web services, open data), information about the data (actuality, resolution etc.), interoperable data.

A lot of information, which can be used for these actions, can be taken from existing information systems maintained by corresponding responsible land administration authorities, i.e. State Land Service in Latvia, National Land Service under the Ministry of Agriculture of the Republic of Lithuania, State Enterprise Centre of Registers in Lithuania, etc. These information systems now are being used to promote operative ensuring of people, businesses, public administrations with actual, reliable, mutually integrated and high-quality data for real property management and related processes, including real property formation, cadastral survey of the land and buildings, real property registration, spatial planning, land use and land management, administration of real property tax, construction, organisation of public services and facilities. This information is essential for planning of real property acquisition or alienation, carrying out business activities related to real properties and their objects – development of infrastructure, construction, site development, etc. Almost every decision made in our day-to-day or working life has a spatial component. 80% of all decisions are based on spatial data. For instance, by planning of new industrial area is necessary to know not only the information related to construction, topography of surface, soils, electrical power, etc., but the structure of surrounding real properties for modelling how industrial area will affect their future use, too.

Key words: real property cadastral data, real property cadastre and register, environment protection, economic growth.

Introduction

The prime origin of cadastre can be found in very ancient times. Cadastre as a State measure was already known in ancient China, Mesopotamia and Egypt. On territory of Latvia cadastre was implemented in the end of 17th century when in 1681 land surveyor Emerling (Berzina et al, 2013) by the King of Sweden was appointed as surveying officer of Livonia and so started the land surveying and land valuation for tax purposes. The history and influence of the cadastre, particularly after 2nd World War, demonstrates that modern cadastre have a much more significant role than their original designers envisaged. Cadastres provide the authoritative description of how people relate to specific land and property (Williamson et al, 2010).

The number of sectors which bases its work on the cadastral data is increasing, becoming more multifactorial, covering both state and private sector, and many sectors of the economy. During the Soviet system land cadastre performed only functions of stock-taking and land use control. With development of market economy improves cadastre, too, and cadastral data are used for planning, socio-economic and rural development policy, as well as for monitoring of implementation of their objectives. Similarly, the use of cadastral information for environmental protection purposes, including analysis of climate changes, is increasing. Therefore it is important continuously to develop cadastral information systems and their interoperability with other national information systems in order to ensure needs of economic sectors in reliable and up-to-date information on real properties.

In 1998 International Society of Surveyors (FIG) conducted the study on potential trends of cadastral registration, results of which lead down to the publication of Cadastre 2014, which reflected a number of scenarios of development of cadastre. One of the aims of the article is to describe how some of these scenarios are fulfilled and how development of cadastre has promoted economic growth in last years. On the other hand the aim is to show how development of other economic sectors has affected development of cadastre and its progress to multipurpose cadastre.

The object of investigation is real property cadastre information system (hereafter – IS Cadastre) in complex with other geographic information systems as components of land administration system.

Role of cadastre in land management

The land is a unique resource and availability of this resource is limited, because its availability does not increase, but is continuously decreasing. Nowadays there more and more have been concerns about the lack of land. This tension is caused by several factors. Economic growth leads to the demand for land both for agricultural purposes and construction. Population on the Earth is increasing, demand for food products and a living space is increasing, therefore information on land use, property rights and its distribution is becoming increasingly important (Boruks A., 2001).

In scientific literature, describing the land as resource, there are highlighted four main functions of land management – land tenure, land value, land use and land development. Modern land registration system deliver an essential infrastructure and encourage integration of the processes related to land tenure (securing and transferring of rights in land), land value (valuation and taxation of land), land use (planning and control of the use of land), and land development (implementing utilities, infrastructure and construction, planning). The cadastre remains as most important
tool, because it is capable to support all functions in the land management paradigm and provides a country with the infrastructure to implement land related policies and management strategies.

In the situation where the demand for land resources is comprehensive, one of the most important functions of land management is land tenure. Without efficient, accessible, non-discriminatory and transparent land registration systems to society cannot be guaranteed full security of land tenure and enjoyment of real property rights. Consequently, the land tenure plays a key role in effective land use. It is important to emphasize also that the land tenure has clear position regarding ownership disputes. Historically European countries have developed several different types of land registration systems, which provide information on land tenure. Cadastre’2014 stressed two sources of land tenure – Land Register, in some countries known as Landbook, and Cadastre. Usually cadastre provides information about the object and answers the following questions:

- HOW? - for what purpose cadastral units used;
- WHERE? - where cadastral unit is located;
- HOW MUCH? – data about area of the land and its distribution, buildings, located on the land, etc.;
- WHAT? - assessment of real property and its objects;

In his turn Land Register in principle focuses on the link to the real property owner. Land Registry and cadastre are complementary to each other and operate as interactive, but interdependent systems. On the principle are based registration systems in many European countries, including Latvia. But there are countries, i.e. Lithuania, where information about real properties and their owners is recorded and maintained in unitary information system.

Real property cadastre and register system in Lithuania includes digital, descriptive (textual) and graphical data in one system. The system is administered by the State Enterprise Centre of Registers, having Central Unit in Vilnius and Branch Offices in the counties (10), also Local Divisions (40) in the regional centres and towns. Real property cadastre and register system cover the whole country and contains comprehensive data on real properties, including land, construction works, flats and premises. The system provides data on legal possession of real properties, encumbrances, servitudes, legal facts and information about mortgages in this way securing citizens, title to real property. Real property cadastre and register data are collected in the central databank, which contains information about more than 6 million real properties and related rights. Information from the central databank is available to domestic customers and international users. Entire territory of Lithuania is divided into 1403 cadastral areas and 9929 blocks. The size of cadastral area in the rural territories is about 4300 ha. The territory of a city is assigned to one cadastral area. Boundaries of cadastral area may not cross the boundaries of municipalities (Daugaliene, 2004; Kasperavičius, 2012; Lietuvos, 2010), Parsova et all, 2012).

Information stored in the real property register databank is reliable and actual, which is ensured by the datatransfer network providing on-line connection between the central databank and local offices.

Land is enormously valuable asset, typically forming of national wealth in developing countries (Kunte, 1998). Income from land is acquired in different ways, so it can be said that the land in use is a multi-purpose resource. As shown in, Functions of land use can be divided into four large groups (Figure 1):

- use of the land for environmental protection;
- use of the land for production;
- use of the land for social functions;
- use of the land for housing or the urban features.

![Multifunctional Land Use](image)

Figure 1. Functions of land use
The mentioned functions are very closely correlated and dependent. Changes in agricultural and agro-environmental land use and management are affected by regional policy and many non-policy factors, such as climate change, demographic change and globalisation. The environmental implications of changes in agricultural land use are complex, because they can make an impact on other agricultural land uses, alter the mix of arable crops, permanent crops and pastures, or change property-rights related to land and water) (OECD, 2009). For implementation of mentioned functions is required relevant information, including information about the land. It has been proved that 80% of all official decisions is based on spatial data, including cadastral based information.

If early in the beginning cadastre was established for fiscal purposes, the modern cadastre should to provide many functions. Therefore regarding cadastre the term “multipurpose cadastre” is used. Mission of multipurpose cadastre is to provide information for needs of all land-use functions. The cadastre is fundamentally responsible for sustainable development of land as one of the most fundamental natural resource. Use of the land is very varied, it is multifunctional use, therefore cadastral information is necessary for well-balanced and sustainable land use-driven decisions making regarding appropriate land use development functions.

One of the land use functions is food production or agriculture which fundamentally is a spatially specific activity, to provide rural development is necessary the information about real property structure and its fragmentation in rural area. Cadastre contains such information not only about real property itself, but also about its composition, types of land use, purposes of land use, etc. As land resources become more rare, society is forced to regulate land use. Land consumption and urban sprawl cannot be stopped but steered and controlled. Land use planning law defines what land use is desired and allowed or forbidden. Land use planning defines legal objects of the land, which can have the effect of restricting land property. A territorial development plan is the planning document where are identified possibilities, directions and limitations of the development of local municipality and perspective land use, including development of all kind of construction, i.e. construction of transport and utility infrastructure (Ministry of Regional Development and Local Government, 2009). These plans are relatively detailed, they reflect the present and planned (permitted) utilisation of the territory and the restrictions on the utilisation of such territory, planned use in long-term (12 years) perspective for every land parcel is in this plan is determined. It is a fact that most planning processes are very time-consuming with up to 75% being devoted to data acquisition and preparation. Only 25% is left for effective planning work. With the new cadastre this ratio can be reversed to 25%: 75% (Kaufmann, J. 2008). Sustainable land use planning needs cadastre as pre-requisite.

Land policy should be based both on reliable and up-to-date spatial data, and information about real properties, land use and its perspective. For implementation of land policy in Latvia has been developed project of Land Administration law, where a major attention is focused on rational use of land resources and land protection. This law intends the task to develop a land report on land for assessment of key aspects of land policy – land as resource, land as object in rights, land as object of value. The land report will provide clear and actual information for definition of land policy priorities, improvement of land policy and assessment of effectiveness of policy development and implementation. The land report will be used by state and municipality institutions responsible for realisation of land policy. Preparation of summary will be based on cadastral information as well as on information from other public information systems.

**Cadastre for environment protection**

Climate change, food shortage, energy scarcity, urban growth, environmental degradation, natural disasters – all these challenges relate to governance of land and cadastral information. With growing danger of an environmental collapse caused by the over-utilization of natural resources and land resources in a non-sustainable manner, societies has developed strategies and created laws for environmental protection. In strategy of EU for sustainable development as one of the main purposes is defined environmental protection, preserving capacity of the land to support life in all its diversity, considering limitation of natural resources. Regulations in most cases have the effect of placing restrictions on the freedom of land use given to the rightful claimants in principle by their property right. No one who owns land in most areas of the world can simply use it as they wish. All public restrictions existing on properties should be well documented in public registers (UNECE, 2010), because they affect not only use of the land, but also its market value. Data modelling and extension of cadastres with RRR (Right – Restrictions – Responsibilities) is the direction which determines tendencies in real property registration in recent years, i.e. Latvia and Lithuania. Nowadays one of the most important legislative documents prescribing types of real property encumbrances and process of their determination in Latvia is Protection zone law. In Lithuania the Law on Land and Resolution No 343 of the Government of the Republic of Lithuania of 12 May 1992 regulate of establishment restrictions and protection zones. Protection zones are certain areas, the task of which is to protect different types of objects from the undesirable external effects, to ensure the exploitation and safety thereof or to protect the environment and people from the harmful effect of an object. According the law one of the types of protection zones are environmental and natural resources protection zones what are specified around objects and territories, which is significant from the point of view of environmental protection and conservation and the rational utilisation of natural resources (Figure 2). Main task thereof shall be to decrease or eliminate the effects of the anthropogenic negative impact on the objects for which the protection zones have been determined. Protection zone law prescribes that all types of protection zones and encumbered territories have to be determine in local government spatial plans.
Figure 2. An example of protection zones on territorial plan of municipality

Due to global warming society is increasingly facing with natural disasters, and in Baltic countries due to rainfall caused by climate changes is more often observed river flooding. Disaster risks must be identified as area zones in the land use plans and the land information system with the relevant risk assessment and information attached (UN-HABITAT/FAO, 2010). In municipal territorial plans are defined and represented risk flooding areas. Because for development of spatial plans are also used spatial cadastral data about land parcel boundaries, it is possible to identify risk zones for each individual property, as well as to determine appropriate land use restrictions, such as prohibition to erect permanent buildings in these areas.

Restrictions established in territory development plans are recorded in IS Cadastre, and these restrictions are taken into account in determining the value of property for tax purposes.

For the environmental issue it is very important to provide information about land cover and vegetation, and historical graphic information about land cover. In IS Cadastre is maintained information on types of land use (arable land, grassland, woodland, scrub, built-up land, etc.). At present information on the types of land use mainly is obtained from cadastral land survey documents, therefore not always it is up-to-dated. Direction, in which would be necessary to act in development of IS Cadastre, is to provide ability to automate updating of types of land use, using cartographic materials in appropriate scale with updating cycle is 5 years.

The linkage between climate change and sustainable development is self-controlling. Cadastral core data are a successful base for the climate change theme. Information, maintained in IS Cadastre on existing buildings, their age and depreciation can be used to make decisions on necessary measures to limit greenhouse effect, because using this data can be made forecast of heat loss in urban areas. Such information also can be used to assess the quality of the existing housing stock and need in planning of new building sites.

One of the requirements in the development of cadastre is the thesis of Cadastre’2014, that cadastre is methodically arranged public inventory of data concerning all legal land objects in a certain country or district. They are defined either by private or by public law. Information will show the complete legal situation of land, including public rights and restrictions. It may be said with assurance that the IS Cadastre in Latvia and Lithuania complies with advanced thesis, but problem what necessary to solve in nearest future is – how to achieve actuality and reliability of information of land use restrictions.

Role of cadastre in real estate market development

Secure land tenure and property rights enable investments in improving of dwelling houses and households, create incentives not only for development of good environmental management, but also provides new economic opportunities. It is one of the factors contributing in economic growth in the real property market development and is linked to a number of factors influencing the market.

According to land market model developed by Peter Dale (Dale, 2000) for stable and efficient land market that encourages sustainable development should be developed clear definition and administration of property rights, minimum set of restriction on property use consistent with the common good, simple and inexpensive way to transfer property rights, transparency in all matters relating to the land, and availability of capital and credits.

Above have described IS Cadastre and cadastral information maintained in this system – clear definition of the system, registration of property rights, data on the restriction on property use, etc. But as already mentioned, important factor for successful activity of real property market are conditions for transfer of property rights. The security of real property transactions should be enhanced by identifying and protecting property rights trough establishment of efficient system for the registration, systematisation and updating of real property data, based on up-to-date Land Register and cadastre records.
Taking into account, that land registration system of Latvia is composed of Land Register and IS Cadastre, in case of property transaction is necessary to realise 5 required procedures, which generally takes 18 days. Comparing with Lithuania, where land registration system is single, for property transaction is necessary to realise 3 required procedures, which generally takes only 18 days.

The database of the real property register in Lithuania integrates data on land parcels and construction works into one system. Information stored in the real property register databank is reliable and actual, which is ensured by the data transfer network providing on-line connection between the central databank and local offices. Notaries in Lithuania have direct access to the central database of the real property register to check the information about real property and its legal status in real time.

Cadastral data are rendered from the central database in accordance with the provisions of the Law of Real Property Cadastre of the Republic of Lithuania and the Law Real Property Register.

Summary and analytical cadastral data is prepared by the Manager of the Cadastre upon the request of data recipients. Summarized and systematized cadastral data, various statistics and analysis are rendered in accordance with agreements between the Manager of the Cadastre and data recipients (Daugaliūnė, 2004).

Real Property Cadastre and Register has a good communication with other cadastres and registers operating in Lithuania.

Principles for developing modern real property registration system in Lithuania: 1) system must be simple; 2) system must be economically based – the income generated from the system operation must cover system maintenance costs; 3) the best ideas from other countries must be used and adapted to the specific situation; 4) The system must be developed for the future, it means it can not be directed to solve the specific, local tasks; 5) one unified property administration system, that merges cadastral and registration data, will be the most effective and simple system for the end users. (Kasperavičius, 2012).

Real property registration system is today also regarded as a part of nation basic economic infrastructure. It plays an important role in the social and economic activities of a nation and it to supports a number of functions in the economic live. In this capacity it has to function and serve different business areas and activities.

This example shows that cadastral systems, which provide information about real properties and ownership rights, have significant advantages, comparing with systems where information about property rights are kept in separate cadastral information system. Also buyers can suffer from insecure dealings and fraud. Precise responsibility such cases reduce to a minimum. Cadastre provide not only a strong foundation for providing clarity in terms of identifying of owners, spatial extent and rights, but also ensure information about value of particular property and its influencing factors. Cadastral valuation of real properties both in Latvia and Lithuania is one of components of cadastre and is based on IS Cadastre data and data about transactions on real property market. Consequently, cadastral values, calculated and maintained in IS Cadastre, fit with trends on real property market and can serve as basis to get a view on property market value, too, because in Latvia real property values determined in cadastral valuation process are tended to reach 75 % level of real property market value.

Challenges for development of cadastre

Information about land is one of the basic information issues. Cadastre information provides data for innumerable activities – facilitates for economic growth by secure investments in land and property development, security in environment protection and use of natural resources, challenges in sphere of climate change and consequences of natural disasters. Taking into account the multifunctional use of cadastral information, it states, that despite the cadastral core functionality, is necessary to provide data for fiscal purposes. Development of cadastre in future should be dynamic and have a demand-driven focus. Consequently, the development of cadastral should be continually reviewed and adapted to today's and tomorrow's requirements in order to support good decision making and land governance, better managed and facilitate negative consequences of changes.

One of the challenges for cadastre is to maintain and improve the quality of data on land. Data quality embraces many different aspects, like compliance with nowadays, purpose of land use, positional and semantic accuracy – correct attribution of objects. There is created variety of indicators and evaluation system to assess efficiency of data quality control operations. Even countries are ranked according to their economic development by assessing their credit rating. Similarly can be evaluated existing land registration systems. As effective can be recognized cadastre which can be designated by AAA. It means that cadastre is:

- Authorative – official environment created within legal frame;
- Assured – it is guaranteed by government that registration system is authentic, complete and comprehensive;
- Accurate – information is obtained on the ground, is reliable, precise and updated.

In other words - information stored in IS Cadastre should be official and reliable.

Cadastre in Latvia and Lithuania fully correspond to first two A – their operation is based on legislative acts, responsibility of their maintenance is delegated to national authorities, and cadastral data cover the nearly 100% of country territory. However, one of the main challenges in future is to ensure that cadastre could be described by third A, it means, that no contradiction between situation in the field (reality) and registered data.

The amount of use of cadastral data mainly is determined by actuality of the data, changes of which in the real world are reflected in the databases. Taken into account, that changes today are so fast, it is clear that traditionally used
methods of updating of cadastral data are not able to provide adequate necessary actuality. Therefore the future of cadastral is located and linked with development and creation of network, of interrelated organizations and their concerned maintained information systems. It means that interoperability of cadastral and other registration systems is important goal for nearest future.

One of the factors which should be considered in future development of cadastral, is development of technologies. Comparing the changes that occurred over the past 10 years, it can be concluded that technologies are changing rapidly. More and more in obtaining of the data are used GPS and remote sensing technologies, which increasingly enable use of data modelling techniques. If 10 years ago one of the challenges was to ensure accessibility of cadastral data 24 hours per day and 7 days in a week, today development of mobile telecommunication technologies allow to connect institutions and people to land registration system via personal mobile phone and use spatial and textual real property data. Such development of mobile phone applications will provide more comprehensive use of cadastral data. Technology become as an increasingly important element in any step of development and use of cadastral data, but nevertheless should be taken into account that it is only tool for ensuring of information availability in efficient and comprehensive way in order to support sustainable development of society.

With development of technologies are increasing opportunities created by technologies to use their results by in society, including use of spatial data for different purposes. It has been mentioned, that about 80% of all decisions are based on spatial data so we can consider as spatially enabled society. Spatially enabled society obtain benefits from a wide range of spatial data, information, and services as a mean serving to organisation of land related activities. Spatial enablement is a concept that adds location to existing information and thereby unlocks the wealth of existing knowledge about the land, its legal and economic situation, its resources, potential use and hazards. Spatial enabled society is based on cadastral data because cadastral provides a strong foundation for integrating and linking spatial information from different sources.

Conclusions

Cadastral development from its beginning to present day shows increasing role of updated information about the land. While initially this information served to complement the royal treasury, nowadays cadastral information plays an important role in economic development. It is important that in the country is established land registration system what supports governance in sustainable development, provides all security of tenure and real property rights, facilitates real estate investments and transactions an ensure effective and transparent property valuation, land-use planning and sustainable land development. It is worth emphasizing the fact that the country's economic and industrial development sets new challenges for the cadastral and land registration and it for the responsible authorities creates a new challenges, to ensure dynamic and demand-driven focus in the development of cadastral in future. Consequently, the development of cadastral should be continually reviewed and adapted to today's and tomorrow's requirements in order to support good decision making and land governance, better managed and facilitate negative consequences of changes. It is important continuously to develop cadastral information systems and their interoperability with other national information systems in order to ensure needs of economic sectors in reliable and up-to-date information on real properties.

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Requirements and Chemical Composition of Organic Vermicompost Produced in Lithuania

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Aleksandras Stulginskis University, Lithuania

Abstract

In the article the requirements established for the production of organic vermicompost in Lithuania are analyzed. It was found that in Lithuania organic biohumus is usually made from farmyard or horse manure with the help of earthworms Eisenia fetida or Dendrobaena veneta. Manure should be used only from small farms or farms with less than 300 livestock units. In order to obtain confirmation by the certification authority that the produced biohumus complies with EU regulations and national legislation a detailed chemical composition analysis by an accredited laboratory and scientific recommendation must be submitted. The certification authority shall verify whether all the materials contained in the vermicompost on the basis of Regulation (EC) No.889/2008 Annex I are allowed for use in organic production. If all the requirements are met the certification authority shall issue a permit to use the produced vermicompost in organic production. Examination of the chemical composition of organic vermicompost showed that it contained 43.65% of dry and 49.43% of organic matter, 24.26% of organic carbon, 4.78% of humic and 0.42% of fulvic acid, 1.67% of total nitrogen (N), 0.46% of total phosphorus (P), 1.49% of total potassium (K), 4.51% of calcium (Ca), 0.74% of magnesium (Mg), 0.56% of iron (Fe), 22.88 mg kg⁻¹ of boron (B), 216.88 mg kg⁻¹ of manganese (Mn), 3.23 mg kg⁻¹ of cobalt (Co), 146.87 mg kg⁻¹ of zinc (Zn), 1.74 mg kg⁻¹ of molybdenum (Mo), and 20.13 mg kg⁻¹ of copper (Cu). pH value was 7.6. Organic biohumus has been contaminated by heavy metals, the amount of cadmium (Cd) comprised 0.35 mg kg⁻¹, Nickel (Ni) - 6.92 mg kg⁻¹, lead (Pb) - 11.59 mg kg⁻¹, chromium (Cr) - 7.11 mg kg⁻¹, and Cr (VI) residues were not found.

Key words: organic farming, biohumus, chemical composition.

Introduction

Under the influence of human activities large amounts of organic waste are produced from which a considerable quantity is biodegradable and it must be sorted out in order not to pollute the environment. One of the methods is their composting while the produced compost can be used for the fertilization of different plants and soil improvement. Composting and vermicomposting technology is widespread and successfully used for the processing of organic materials. Vermicomposting is a much faster processing of organic waste in the result of which quality organic fertilizers and soil improvers such as vermicompost and biohumus are produced. For this purpose different types of earthworms are used. Studies have shown that biohumus is a much better fertilizer than manure (Kaushik, Garg, 2003; Garg et al., 2006; Артемьёв, 2007; Pekarskas, 2008; Титов, 2012).

Manure is recommended to be processed into biohumus as it significantly reduces environmental pollution while the effectiveness of vermicompost on soil and plants is higher than that of manure. Fertilizing with biohumus improves soil physical and chemical properties, increases its biological activity. This is particularly important in organic production, where it is prohibited to use synthetic chemical fertilizers (Albiach et al., 2000; Dominguez, 2004; Игоинин, 2006; Заманов и др., 2007; Lazcano et al., 2008).

In the production of vermicompost manure of various animals, organic wastes of different origin including green waste are used. From the chemical composition of organic materials used in vermicomposting largely depends chemical composition and quality of the produced vermicompost itself. It differs greatly depending on the origin and composition of raw materials used in vermicomposting (Mitchell, 1997; Albanell et al., 1988 Suthar, 2008; Atiyeh et al., 2001; Loh et al., 2005).

The produced biohumus is directly used in crop fertilization or soil improvement as well as for the production of liquid organic fertilizer, biological agents and various organic mixtures. Studies in different countries have shown that biohumus and liquid organic fertilizers produced from it are very effective in growing most of the crops. Under their influence increases not only the yield of crops grown, improves the quality of products harvested, but also soil properties are improved (Zaller, 2007; Atiyeh et al., 2000; Arancio et al., 2004, 2005; Archana et al., 2009; Pekarskas et al., 2011; Pekarskas, 2012).

To manufacture products which can be used in organic farming a very important is the origin of constituent parts of vermicompost. According to the requirements of the Commission Regulation (EC) No. 889/2008 "Fertilizers and soil conditioners“ and Regulation (EC) no. 834/2007 in organic production it is prohibited to use organic fertilizers from industrial agriculture farms while manufacturing of various fertilizers and soil conditioners no materials treated with synthetic substances can be used. Producing fertilizers and soil improvers in organic production is allowed to use: 1) dry animal and dehydrated poultry manure (substances obtained from industrial farming are forbidden); 2) animal excrement compost containing poultry manure and animal manure compost (materials obtained from industrial farming are forbidden); and 3) liquid animal excreta (used after controlled fermentation and (or) diluted in a certain ratio. Substances obtained from industrial farming are forbidden); 4) various by-products of animal origin (maximum chromium (Cr) (VI) concentration in dry matter – 0 mg kg⁻¹), such as blood hoof horn, bone meal or bone meal without gelatin, fish and meat meal, dairy products, etc (Council Regulation (EC) no. 834/2007; Commision Regulation (EC) no. 889/2008).

The aim of the study – to investigate chemical composition and analyze the requirements for produced in Lithuania organic vermicompost.
Material and methods

Samples of the vermicompost produced in Lithuania which is suitable for use in organic production were taken from various manufacturers who certified biohumus as organic or their production of vermicompost is in line with EU regulations (Council Regulation (EC) no. 834/2007) and correspond to the requirements of Commission Regulation (EC) no. 889/2008. Totally, 20 vermicompost samples have been taken to investigate. Studies of the chemical composition of vermicompost were conducted in the Lithuanian and foreign laboratories.

Dry matter content of the biohumus was determined by drying at 105 °C, organic matter – by the combustion at 500 °C, organic carbon – in the carbon analyzer, total Kjeldahl nitrogen (N) – by Kjeldahl’s apparatus, total phosphorus (P) by spectrophotometric method with ammonium molybdate, total potassium (K) by flame photometric method, Ca, Mg and Fe by atomic absorption spectrometry with flame atomizer, B, Co, Mo, Mn, Cu, Zn, Cd, Ni, Pb – by induced plasma spectrometry, pH – by electrochemical, while humic and fulvic acids by titrometric methods.

The studied biohumus was produced from cattle and horse manure as well as other organic waste materials which are permitted by EU regulations. For the vermicomposting of organic materials Eisenia fetida earthworms were used. In the production of vermicompost different vermicomposting technologies were applied.

Standard deviations of the indices of chemical composition of vermicompost were calculated using the Excell program.

Results

In order to produce environmentally friendly biohumus in Lithuania it is essential not only to be in line with the EU regulations, but also with national legislation. According to Lithuanian organic agriculture regulations a farm where in one place (a barn or a group of barns) are kept not more than 300 livestock units is considered to be an industrial production livestock farm. Therefore producing organic biohumus manure should be used only from small farms or farms with less than 300 livestock units. This is a mandatory requirement and should be strictly observed.

According to the EU regulations vermicompost can be produced from composted or fermented household waste (a product derived from the primary household waste which has been submitted to composting or to anaerobic fermentation for biogas production; exceptionally vegetable and animal household waste; only when produced in a closed and monitored collection system approved by the member states) where the maximum permissible concentrations of heavy metals in dry matter are within the limits of: cadmium (Cd) – 0.7 mg kg⁻¹; copper (Cu) – 70 mg kg⁻¹; nickel (Ni) – 25 mg kg⁻¹; lead (Pb) – 45 mg kg⁻¹; zinc (Zn) – 200 mg kg⁻¹; mercury (Hg) – 0.4 mg kg⁻¹; chromium (Cr) (total) – 70 mg kg⁻¹; chromium (Cr) (VI) – 0 mg kg⁻¹ (Commision Regulation (EC) no. 889/2008). Currently these organic materials cannot be used for organic vermicompost production in Lithuania because the procedure of their use has not been confirmed yet.

In Lithuania organic biohumus is mostly produced from the farmyard or horse manure and using other allowed organic matter (Пекарскас, Жичкус, 2013). In the production of vermicompost various technologies are applied and most commonly earthworms Eisenia fetida (Savigny, 1826) or Dendrobaena veneta (Rosa, 1886) are used.

<table>
<thead>
<tr>
<th>Constituents</th>
<th>Content %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry matter</td>
<td>43.65±1.84</td>
</tr>
<tr>
<td>Organic matter</td>
<td>49.43±2.03</td>
</tr>
<tr>
<td>Organic carbon</td>
<td>24.26±1.70</td>
</tr>
<tr>
<td>Humic acid %</td>
<td>4.78±0.25</td>
</tr>
<tr>
<td>Fulvic acid %</td>
<td>0.42±0.02</td>
</tr>
<tr>
<td>pH_KCl</td>
<td>7.6±0.10</td>
</tr>
<tr>
<td>Total nitrogen (N)</td>
<td>1.67±0.08</td>
</tr>
<tr>
<td>Total phosphorus (P)</td>
<td>0.46±0.03</td>
</tr>
<tr>
<td>Total potassium (K)</td>
<td>1.49±0.07</td>
</tr>
<tr>
<td>Ca</td>
<td>4.51±0.16</td>
</tr>
<tr>
<td>Mg</td>
<td>0.74±0.04</td>
</tr>
<tr>
<td>Fe</td>
<td>0.56±0.03</td>
</tr>
</tbody>
</table>

Lithuania has a strict regulatory regime of organic vermicompost production. Biohumus producers wishing to obtain approval of the certification authority that their manufactured biohumus meets EU regulations and national legislation must provide a detailed analysis of chemical composition and scientific recommendation from an accredited laboratory certifying that the produced biohumus will be effective. The certification authority shall verify whether all the materials contained in the vermicompost based on the Regulation (EB) No.889/2008 Annex I are allowed for use in organic production. If all the requirements are met, the certification authority shall issue a permit to use vermicompost for organic production. Since 2013 supporting documents and the process in Lithuania is controlled by the State Plant Service under the Ministry of Agriculture, but until then these functions were performed by the certification organization SE ‘Ekoagros’.

Examination of the chemical composition of produced in Lithuania organic vermicompost has shown that it contains 43.65% and 49.43% of dry organic matter, 24.26% of organic carbon, 4.78% of humic and 0.42% of fulvic
acids, pH value of the vermicompost was 7.6. Organic biohumus contained 1.67% of total nitrogen, 0.46% of total phosphorus, 1.49% of total potassium, 4.51% of calcium, 0.74% of magnesium and 0.56% of iron (Table 1).

Produced in Lithuania biohumus was rich in trace elements and contained 22.88 mg kg\(^{-1}\) of boron, 216.88 mg kg\(^{-1}\) of manganese, 3.23 mg kg\(^{-1}\) of cobalt, 146.87 mg kg\(^{-1}\) of zinc, 1.74 mg kg\(^{-1}\) molybdenum and 20.13 mg kg\(^{-1}\) of copper. Organic biohumus was not contaminated by heavy metals, it contained 0.35 mg kg\(^{-1}\) of cadmium, 6.92 mg kg\(^{-1}\) of nickel, 11.59 mg kg\(^{-1}\) of lead and 7.11 mg kg\(^{-1}\) of chromium, while Cr (VI) was not detected (Table 2).

<table>
<thead>
<tr>
<th>Constituents</th>
<th>Content mg kg(^{-1})</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>22.88±1.52</td>
</tr>
<tr>
<td>Mn</td>
<td>216.88±12.41</td>
</tr>
<tr>
<td>Co</td>
<td>3.23±0.08</td>
</tr>
<tr>
<td>Zn</td>
<td>146.87±9.22</td>
</tr>
<tr>
<td>Mo</td>
<td>1.74±0.04</td>
</tr>
<tr>
<td>Cu</td>
<td>20.13±1.16</td>
</tr>
<tr>
<td>Cd</td>
<td>0.35±0.02</td>
</tr>
<tr>
<td>Ni</td>
<td>6.92±0.21</td>
</tr>
<tr>
<td>Pb</td>
<td>11.59±0.42</td>
</tr>
<tr>
<td>Cr</td>
<td>7.11±0.34</td>
</tr>
<tr>
<td>Cr (VI)</td>
<td>0.00</td>
</tr>
</tbody>
</table>

### Table 2. Amount of trace elements and heavy metals in produced in Lithuania organic biohumus

**Conclusions**

In Lithuania in order to obtain approval of the certification authority that the manufactured biohumus meets EU regulations and national legislation, a detailed analysis of chemical composition of the product and scientific recommendation from an accredited laboratory certifying that the produced biohumus will be effective must be provided. The certification authority shall verify whether all the materials contained in the vermicompost based on the Regulation (EB) No 889/2008 Annex I are allowed for use in organic production. If all the requirements are met the certification authority shall issue a permit to use vermicompost for organic production.

In Lithuania organic biohumus is mostly produced from the farmyard or horse manure with the help of earthworms Eisenia fetida or Dendrobaena veneta. The manure should be used only from small farms or farms with less than 300 livestock units.

Produced in Lithuania organic vermicompost contained 43.65% of dry and 49.43% of organic matter, 24.26% of organic carbon, 4.78% of humic and 0.42% of fulvic acids, 1.67% of total nitrogen (N), 0.46% of total phosphorus (P), 1.49% of total potassium (K), 4.51% of calcium (Ca), 0.74% of magnesium (Mg), 0.56% of iron (Fe), pH value was 7.6. The produced biohumus was rich in trace elements and contained 22.88 mg kg\(^{-1}\) of boron (B), 216.88 mg kg\(^{-1}\) of manganese (Mn), 3.23 mg kg\(^{-1}\) of cobalt (Co), 146.87 mg kg\(^{-1}\) of zinc (Zn), 1.74 mg kg\(^{-1}\) of molybdenum (Mo) and 20.13 mg kg\(^{-1}\) of copper (Cu).

Organic biohumus was not contaminated by heavy metals, it contained 0.35 mg kg\(^{-1}\) of cadmium (Cd), 6.92 mg kg\(^{-1}\) of nickel (Ni), 11.59 mg kg\(^{-1}\) of lead (Pb), 7.11 mg kg\(^{-1}\) of chromium (Cr), while Cr (VI) residues were not detected.

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The Influence of Long–term Organic Farming on Segetic Flora Composition in
the Eastern Galega (Galega orientalis Lam.) Crop
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Abstract
Investigations of long-term organic farming effect on the eastern galega (Galega orientalis Lam.) segetic flora species composition were
carried out at Experimental Station of Aleksandras Stulginskis University in 2007-2011. The galega field was dominated by loam Calc(ar)iEpihypogleyic Luvisol - LVg-pw-cc soil, which has been r alkaline (pH 7.4-7.6), having medium humus content (2.00 - 2.88%), phosphorus (P2O5
165-200 mg kg-1) and small and medium amount of potassium (K2O 90-142 mg kg-1). There in galega field after spring barley cover crop cutting were
found 51 segetic flora plant species. Crop was dominated by short - lived spring and short-lived overwintering weed species. Number of segetic flora
species decreased to 32 units or 19 species during the first year of galega use. Segetic flora species composition varied little from the second year of
use and there found 17-20 species of which 11-14 were perennial. Perennial weeds, spreading seeds as well as reproducing by seeds and vegetative
began to dominate. Crop was dominated by small, medium, and weak alkaline, moderately rich, rich and the very rich with nitrogen, moderately
moist and humid and moderately warm and warm soils and indifferent plants. The highest number of weeds in galega was found after cutting of
spring barley cover crop, in the first year of using the number of weeds decreased significantly, and the weed mass decreased only slightly. In the
second year of galega cultivation weeds, compared to the first year of cultivation decreased significantly. Comparing the third and fourth years of use
galega crop, no significant differences of weeds number and weight were found.
Key words: eastern galega, organic farming, segetic flora.

Introduction
Eastern galega (Galega orientalis Lam.) is a perennial herbaceous fabaceae plants. One galega plant can have 520 stems. Stems are upright, hollow, upper branching. Under favourable conditions grow 1.0-1.5 m and taller. Root
taproot, rhizobia bacteria fixate nitrogen. Leaves are large, complex, non-porous and pinnate. They consist of 9-15 eggshaped or oblong lateral leaflets. Galega grow in all soils, it is important only in that they contain enough nutrients and
moisture. The most abundant harvest obtained in the second and third year, relatively resistant to wintering conditions
and drought. In spring, grows faster than other leguminous perennial grasses. In one place they can grow for 7-15 years
and longer. They are grown alone or in a variety of perennial grass mixtures. Galega used for animal feed, and more
recently explored as well as the energetical plants (Spruogis, 1999; Raig, Meripõld, 2001; Kryževičienė et al., 2008;
There is a lack of studies on eastern galega growing under organic farming system. The influence of long - term
organic farming on segetic flora species composition in galega has been little studied.
The aim - to investigate the influence of long – term organic farming on the eastern galega (Galega orientalis
Lam.) segetalic flora composition.
Material and methods
Investigations of long-term organic farming affect on the eastern galega (Galega orientalis Lam.) segetalic flora
species composition were carried out at Experimental Station of Aleksandras Stulginskis University in 2007-2011. The
galega field was dominated by loam Calc(ar)i-Epihypogleyic Luvisol - LVg-pw-cc soil, which has been alkaline (pH
7.4-7.6), having medium humus content (2.00-2.88%), phosphorus (P2O5 165-200 mg kg-1) and small and medium
amount of potassium (K2O 90-142 mg kg-1).
Soil samples for testing of agrochemical properties were taken before galega sowing from 0-20 cm depth. Soil
samples were taken from each stripe from 8-12 different locations with three repetitions. Soil pH was determined
mobile phosphorus and potassium - A-L (Egner-Rimo-Domingo) (GOST 26208-84) methods.
Eastern galega was sown in 2007, into spring barley 'Ula'. Seed rate - 20 kg ha -1. Field area was 0.70 ha. Three
stripes about 950m-2 each (95 × 10 m) were established for investigations. Galega in this area has grown for green mass
and in some years for seed as well.
Weeds in 2007 were investigated after the cutting of barley cover crop, when galega grew, on 6th of September,
and in 2008-2011 (I-IV years of use) at the beginning of budding - flowering stage in the end of May. Weeds were
identifies in three stripes in six locations, a total of 18 different 0.25 m-2 site area (0.5 × 0.5 m.). Weeds were pulled and
counted, and then weed samples dried at Research Station dryers and weighed. At the same time, the segetic flora
species composition was estimated, registering all growing weeds species, found in investigation area.
Weeds categorized in the ecological groups according to the soil pH, nitrogen, humidity and temperature
The results statistical analysis was performed using the computer program ANOVA (Clewer, Scarisbric, 2001).
Results
There in galega crop after cutting of spring barley cover crop was found in 51 segetics flora plant. Crop was
dominated by short-lived spring and short-lived overwintering weed species both in terms of number of species and
their number and weight per square meter, as before in this field has grown annuals crops. Perennial weeds were not
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spread, although they have been found as many as 17 species or 33.33 percent from all segetic flora species. Already in the first year of galega cultivation segetic flora species decreased to 32 units or 19 species. The largest decrease observed (15 units) of short-lived spring weeds that grow overshadowed by galega plants. Overshadowed and some perennial weeds: *Stachys palustris* L., *Sonchus arvensis* L., *Convolvulus arvensis* L. In the crop began to dominate short-lived wintering, biennial and perennial weed species. Segetic flora species composition has changed very little from the second year of galega use. There were found 17-20 species of segetic flora. Were found only one specie of short-lived weed species, and 4-5 of short-lived wintering species. The short-lived wintering weed species *Myosotis arvensis* (L.) Hill., *Galium aparine* L., *Capsella bursa-pastoris* (L.) Med. was poorly choked by galega plants, especially *Tripleurospermum perforatum* (Merat) M. Lainz. Perennial weeds, spreading seeds as well as spreading seeds and reproducing vegetative began to dominate, taking even 11-14 species from 17-20 species found galega crop (Table 1).

Table 1. Segetic flora species composition in organic eastern galega (*Galega orientalis* Lam.) crop

<table>
<thead>
<tr>
<th>Segetic flora species</th>
<th>Eastern galega after cutting of spring barley cover crop</th>
<th>Eastern galega I y.u.*</th>
<th>Eastern galega II y.u.</th>
<th>Eastern galega III y.u.</th>
<th>Eastern galega IV y.u.</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Galeopsis tetrahit</em> L.</td>
<td>+</td>
<td>-</td>
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<tr>
<td><em>Chaenorhinum minus</em> (L.) Lange.</td>
<td>+</td>
<td>-</td>
<td>-</td>
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<td>-</td>
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<tr>
<td><em>Sonchus asper</em> (L.) Hill.</td>
<td>+</td>
<td>-</td>
<td>-</td>
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<td>-</td>
</tr>
<tr>
<td><em>Chenopodium album</em> L.</td>
<td>+</td>
<td>-</td>
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<td>-</td>
</tr>
<tr>
<td><em>Chenopodium polyspermum</em> L.</td>
<td>+</td>
<td>-</td>
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<td>-</td>
</tr>
<tr>
<td><em>Galinsoga parviflora</em> Cav.</td>
<td>+</td>
<td>-</td>
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<tr>
<td><em>Poa annua</em> L.</td>
<td>+</td>
<td>-</td>
<td>-</td>
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<td>-</td>
</tr>
<tr>
<td><em>Fallopia convolvulus</em> (L.) A.Löve</td>
<td>+</td>
<td>-</td>
<td>-</td>
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<tr>
<td><em>Nagphilum uliginosum</em> L.</td>
<td>+</td>
<td>-</td>
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<tr>
<td><em>Echinodloa crus-galli</em> (L.) P.Beauv.</td>
<td>+</td>
<td>-</td>
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<tr>
<td><em>Persicaria lapathifolia</em> (L.) Gray.</td>
<td>+</td>
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<tr>
<td><em>Polygonum aviculare</em> L.</td>
<td>+</td>
<td>-</td>
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<tr>
<td><em>Stellaria media</em> (L.) Vill.</td>
<td>+</td>
<td>-</td>
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<tr>
<td><em>Euphorbia helioscopia</em> L.</td>
<td>+</td>
<td>-</td>
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<td>-</td>
<td>-</td>
</tr>
<tr>
<td><em>Juncus bufonius</em> L.</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><em>Avena fatua</em> L.</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><em>Brassica napus</em> L.</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><em>Veronica verna</em> L.</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><em>Matricaria discoidea</em> DC.</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><em>Bromus hordeaceus</em> L.</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>19</strong></td>
<td><strong>4</strong></td>
<td><strong>1</strong></td>
<td><strong>1</strong></td>
<td><strong>1</strong></td>
</tr>
<tr>
<td></td>
<td>Short – lived wintering</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Myosotis arvensis</em> (L.) Hill.</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td><em>Lamium amplexicaule</em> L.</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><em>Lamium purpureum</em> L.</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><em>Telapsi arvensc</em> L.</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><em>Galium aparine</em> L.</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><em>Tripleurospermum perforatum</em></td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>(Merat) M. Lainz</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Erysimum cheiranthoides</em> L.</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><em>Veronica arvensis</em> L.</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><em>Capsella bursa-pastoris</em> (L.) Med.</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><em>Conyza canadensis</em> (L.) Cronquist.</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><em>Viola arvensis</em> Murray</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>11</strong></td>
<td><strong>8</strong></td>
<td><strong>4</strong></td>
<td><strong>5</strong></td>
<td><strong>4</strong></td>
</tr>
<tr>
<td></td>
<td>Short – lived winteral</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Arabidopsis thaliana</em> (L.) Heynh.</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1</strong></td>
<td><strong>1</strong></td>
<td><strong>0</strong></td>
<td><strong>0</strong></td>
<td><strong>0</strong></td>
</tr>
<tr>
<td></td>
<td><strong>bienual</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Anagalis arvensis</em> L.</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><em>Erodium cicutarium</em> (L.) L’Her.</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><em>Barbarea vulgaris</em> W.T.Aiton.</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><em>Carum carvi</em> L.</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><em>Arctium tomentosum</em> Mill.</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>3</strong></td>
<td><strong>4</strong></td>
<td><strong>1</strong></td>
<td><strong>0</strong></td>
<td><strong>0</strong></td>
</tr>
<tr>
<td></td>
<td>Perennial, spreading seeds</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Taraxacum officinale</em> F.H.Wigg.</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td><em>Artemisia vulgaris</em> L.</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><em>Rumex crispus</em> L.</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td><em>Cerastium arvense</em> L.</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><em>Plantago major</em> L.</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td><em>Medicago lupulina</em> L.</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

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were no significant changes in numbers of weeds and weed weight. There observed a significant decrease in number of weeds in the second year of use, compared to the first year of cultivation. Assessing weeds in third and fourth years of use galega crop weeds decreased significantly, while the weed mass decreased slightly. There was a significant decrease of weeds in galega crop according to the need for soil 
P. Thereafter in comparison with the IV year of use (Table 3).

Table 2. Segetic flora species composition and their distribution according to ecological groups in organic II-IV year of use Eastern galega (Galega orientalis L.) crop

<table>
<thead>
<tr>
<th>Weed variety</th>
<th>Ecological group of weeds according to pH</th>
<th>Ecological group of weeds according to amount of Nitrogen</th>
<th>Ecological group of weeds according to soil moisture</th>
<th>Ecological group of weeds according to soil temperature</th>
<th>Ecological group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stellaria media (L.) Vill.</td>
<td>7</td>
<td>8</td>
<td>×</td>
<td>×</td>
<td>11</td>
</tr>
<tr>
<td>Bromus hordeaceus L.</td>
<td>×</td>
<td>3</td>
<td>×</td>
<td>6</td>
<td>×</td>
</tr>
<tr>
<td>Myosotis arvensis (L.) Hill.</td>
<td>×</td>
<td>6</td>
<td>5</td>
<td>6</td>
<td>×</td>
</tr>
<tr>
<td>Lamium amplexicaule L.</td>
<td>7</td>
<td>7</td>
<td>4</td>
<td>6</td>
<td>×</td>
</tr>
<tr>
<td>Galium aparine L.</td>
<td>6</td>
<td>8</td>
<td>×</td>
<td>6</td>
<td>11</td>
</tr>
<tr>
<td>Tripleurospermum perforatum (Mérat) M.Lainz</td>
<td>6</td>
<td>6</td>
<td>×</td>
<td>6</td>
<td>11</td>
</tr>
<tr>
<td>Veronica arvensis L.</td>
<td>6</td>
<td>×</td>
<td>×</td>
<td>6</td>
<td>×</td>
</tr>
<tr>
<td>Capsella bursa-pastoris (L.) Med.</td>
<td>×</td>
<td>6</td>
<td>5</td>
<td>×</td>
<td>10</td>
</tr>
<tr>
<td>Artemisia vulgaris L.</td>
<td>×</td>
<td>8</td>
<td>6</td>
<td>6</td>
<td>×</td>
</tr>
<tr>
<td>Plantago major L.</td>
<td>×</td>
<td>6</td>
<td>5</td>
<td>×</td>
<td>×</td>
</tr>
<tr>
<td>Taraxacum officinale F.H.Wigg.</td>
<td>×</td>
<td>8</td>
<td>5</td>
<td>×</td>
<td>×</td>
</tr>
<tr>
<td>Artemisia vulgaris L.</td>
<td>×</td>
<td>8</td>
<td>6</td>
<td>6</td>
<td>×</td>
</tr>
<tr>
<td>Rumex crispus L.</td>
<td>×</td>
<td>6</td>
<td>7</td>
<td>5</td>
<td>15</td>
</tr>
<tr>
<td>Anthriscus sylvestris (L.) Hoffm.</td>
<td>6</td>
<td>6</td>
<td>5</td>
<td>6</td>
<td>×</td>
</tr>
<tr>
<td>Equisetum arvense L.</td>
<td>×</td>
<td>3</td>
<td>×</td>
<td>×</td>
<td>15</td>
</tr>
<tr>
<td>Mentha arvensis L.</td>
<td>×</td>
<td>×</td>
<td>7</td>
<td>×</td>
<td>15</td>
</tr>
<tr>
<td>Poa trivialis L.</td>
<td>×</td>
<td>7</td>
<td>7</td>
<td>×</td>
<td>15</td>
</tr>
<tr>
<td>Tussilago farfara L.</td>
<td>8</td>
<td>×</td>
<td>6</td>
<td>×</td>
<td>15</td>
</tr>
<tr>
<td>Cirsium arvense (L.)</td>
<td>×</td>
<td>7</td>
<td>×</td>
<td>5</td>
<td>×</td>
</tr>
<tr>
<td>Elytrigia repens (L.) Nevski</td>
<td>×</td>
<td>7</td>
<td>×</td>
<td>6</td>
<td>×</td>
</tr>
<tr>
<td>Ranunculus repens L.</td>
<td>×</td>
<td>7</td>
<td>×</td>
<td>6</td>
<td>×</td>
</tr>
<tr>
<td>Achillea millefolium L.</td>
<td>×</td>
<td>5</td>
<td>4</td>
<td>×</td>
<td>×</td>
</tr>
<tr>
<td>Glechoma hederacea L.</td>
<td>×</td>
<td>7</td>
<td>6</td>
<td>6</td>
<td>×</td>
</tr>
</tbody>
</table>
Table 3. Weedness of organic II-IV year of use Eastern galega (Galega orientalis L. m.) crop

<table>
<thead>
<tr>
<th>Year of use of eastern galega crop</th>
<th>Number of weeds m⁻²</th>
<th>Weeds weight g m⁻²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eastern galega after cutting of sping barley cover crop</td>
<td>178.7</td>
<td>118.73</td>
</tr>
<tr>
<td>I year of use</td>
<td>88.3</td>
<td>113.17</td>
</tr>
<tr>
<td>II year of use</td>
<td>60.7</td>
<td>57.98</td>
</tr>
<tr>
<td>III year of use</td>
<td>46.5</td>
<td>48.12</td>
</tr>
<tr>
<td>IV year of use</td>
<td>40.8</td>
<td>41.54</td>
</tr>
<tr>
<td>LSD₀₅</td>
<td>9.25</td>
<td>10.15</td>
</tr>
</tbody>
</table>

Conclusions

There in galega crop after cutting of spring barley cover crop was found in 51 segetic flora plant. Crop was dominated by short-lived spring and short-lived overwintering weed species. Already in the first year of galega cultivation segetic flora species decreased to 32 units or 19 species. The largest decrease observed of short-lived spring weeds that grow overshadowed by galega plants. There were found 17-20 species of segetic flora from II year of use of galega crop. Perennial weeds, spreading seeds as well as spreading seeds and reproducing vegetative began to dominate, taking even 11-14 species.

There organic galega crop (II-IV y.u.) was dominated by small, medium, and weak alkaline, moderately rich, wealthy and very rich in nitrogen, moderately moist and humid and moderately warm and warm soils and indifferent plants. Eastern galega crop weeds according the need for soil pH, nitrogen, humidity and temperature can be attributed to these weeds ecological groups: chickweed (Stellaria media (L.) Vill.), creeping buttercup (Ranunculus repens (L.)), and not attributed to some ecological.

Evaluation of weeds showed the highest amount of weeds in galega crop was after cutting spring barley cover crop. During the first year of use, compared to the crop after cover crop cutting, number of weeds per square meter decreased significantly, while the weed mass decreased slightly. There was a significant decrease of weeds in galega second year of use, compared to the first year of cultivation. Assessing weeds in third and fourth years of use galega were no significant changes in numbers of weeds and weed weight. There observed a significant decrease in number of weeds in III-IV year of use, comparing to the second year of use, while significant decrease of weeds weight was only in comparison with the IV year of use.

References

The Generalised Height-Diameter Equations of Scots Pine (*Pinus sylvestris* L.) Trees in Lithuania

Edmundas Petrauskas, Petras Rupšys

Aleksandras Stulginskis University, Lithuania

Abstract

Scots pine (*Pinus Silvestris L.*) is a dominant tree species in Lithuania. Due to high commercial importance for wood industry the reliable future trends of sustainable use are needed. Traditionally these trends are based on unbiased yield and growth models. Since 1998 the National Forest Inventory in Lithuania has been carried out. Data collected on a permanent sampling plots is a new source for trustworthy empirical material sets that could and should be used to develop new or calibrate existing yield models. Height-diameter equations has been attracting attention in forestry growth modelling. Several mathematical models have been proposed for tree height model completely based on diameter at breast height and generalised height-diameter model based on tree diameter at breast height and stand variables. The objective of the research was to develop a generalised height–diameter model for *Pinus sylvestris* L. in Lithuania with diameter at breast height outside the bark larger than 0 cm. Additionally four generalised height-diameter equations were selected as candidate functions to compare the height-diameter predictions. The parameters of all used models were estimated using an estimation data set and were evaluated using a validation data set. Performance statistics for the generalised height equations included four statistical indexes: mean percentage of absolute bias, precision, Akaike’s Information Criteria, and an adjusted coefficient of determination.

Introduction

Tree diameter at breast height (d) and tree height (h) are the two most important variables used in forest inventory and management. A consistent model of total tree height is often required in forest management and in growth and yield studies. Height of the trees not measured in sample can be estimated using a height–diameter equation. Height-diameter equations for tree species have been long used in forest inventories and growth models for predicting missing total height measurements (Huang et al., 1992,). Height–diameter models can be classified into two basic types according to their independent variables. The first type assumes that tree height is completely dependent on diameter at breast height. The second type includes diameter at breast height and other individual tree and stand level variables such as tree age, site index, stand basal area, stand density, dominant and mean height and dominant and mean diameter at breast height (Kuliešis, 1993). These are also known as generalised models. The generalised height-diameter equations are functions of tree diameter and stand variables and can be applied at the regional level. The first type models require only low sampling effort and are usually locally applied (Soares and Tome, 2002), whereas the second type models demand high sampling effort and are often applied regionally. Many comparisons between different models or ecoregions have been carried out to identify appropriate height–diameter relationships within stands (Huang et al., 1992; Soares and Tome, 2002; Krisnawati, 2010; Rupšys and Petrauskas, 2010; and references therein).

The main objective of this study is to develop a generalised height-diameter equation for *Pinus sylvestris* L. grown in Lithuania. Keeping in mind that the data used in this work are from different stands, both types of equations might have a regional application. In this study, the following stand variables characterising the plots were tested for inclusion in the base height-diameter models: stand age, A, mean diameter, \(d_0\), and mean height, \(h_0\). Several combinations of these variables were also considered. Initial screenings of models were based on the significance of model parameters. To make two models more closely match the reality of height versus diameter at breast height a modification was suggested. A constant, 1.3 was added to the model to avoid prediction of a height less than 1.3 m when diameter at breast height approaches zero. Both graphical and numerical analyses of the residuals were also carried out. The adequacy of the models was determined using the fit statistics calculated for the validation data set.

Material and Methods

Data for developing the models were collected by the National Forest Inventory in 2006-2010 (Kuliešis, at all, 2010) The NFI plots are systematically distributed using a grid of 4x4 km squares with a random starting point. The sample plots are arranged into triangle distributed clusters with a distance between angles of 2 km. Each cluster has 4 sample plots. They are situated on each 250 m length side of square 25 m from its angles. At plot establishment, the following data were recorded for every sample tree: species, diameter over bark at 1.3 m to the nearest millimeter and height to the nearest 10 cm. Diameters were measured with callipers in direction perpendicular to the centre of a sample plot. 3456 plots of Scots pine trees were chosen from the 2006-2010 database. A random sample of 2000 plots (7352 trees) was selected for model estimation, and the remaining data set of 1456 plots (5413 trees) was utilised for model validation. Summary statistics for the diameter at breast height (d), height (h), age (A), mean quadratic diameter (\(d_0\)) on each plot and mean weighted on basal area tree height (\(h_0\)) on each plot of all the trees used for model estimation and validation are presented in Table 1.
Table 1. Characterisation of data set, tree and stand variables

<table>
<thead>
<tr>
<th>Data</th>
<th>Number of trees (plots)</th>
<th>Min</th>
<th>Max</th>
<th>Mean</th>
<th>St. Dev.</th>
<th>Number of trees (plots)</th>
<th>Min</th>
<th>Max</th>
<th>Mean</th>
<th>St. Dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>d (cm)</td>
<td>7352</td>
<td>15.10</td>
<td>82.70</td>
<td>27.35</td>
<td>8.74</td>
<td>5413</td>
<td>15.10</td>
<td>74.30</td>
<td>27.29</td>
<td>8.68</td>
</tr>
<tr>
<td>h (m)</td>
<td>7352</td>
<td>6.70</td>
<td>37.80</td>
<td>22.10</td>
<td>4.45</td>
<td>5413</td>
<td>7.10</td>
<td>37.80</td>
<td>21.98</td>
<td>4.39</td>
</tr>
<tr>
<td>A (yr)</td>
<td>7352</td>
<td>11</td>
<td>221</td>
<td>65.90</td>
<td>23.64</td>
<td>5413</td>
<td>17</td>
<td>192</td>
<td>66.75</td>
<td>23.85</td>
</tr>
<tr>
<td>d₀ (cm) (2000)</td>
<td>15.10</td>
<td>60.59</td>
<td>28.33</td>
<td>4.45</td>
<td>8.12</td>
<td>(1456)</td>
<td>15.10</td>
<td>70.20</td>
<td>28.41</td>
<td>8.35</td>
</tr>
<tr>
<td>h₀ (m) (2000)</td>
<td>7.40</td>
<td>34.35</td>
<td>22.71</td>
<td>4.64</td>
<td>4.52</td>
<td>(1456)</td>
<td>7.16</td>
<td>34.74</td>
<td>22.66</td>
<td>4.52</td>
</tr>
</tbody>
</table>

Candidate functions

The objective of the research was to develop a generalized height–diameter model for Scots pine trees in Lithuania. Krisnawati et al. (2010) recommended the Richards function and Lundqvist–Korf as probably the most flexible and versatile functions available for modelling height–diameter relationships, but no particular function has been identified as superior. When selecting height–diameter functions, both data-related and reasonable biological criteria should be considered simultaneously. According to Soares and Tome (2002), the function form used to model the height-diameter relationship should: (i) increase monotonically, (ii) have an upper asymptote, and (iii) have an inflection point. Although height–diameter scatter plot analyzed by Scots pine trees had strong linear relationship we used in this paper the non-linear models in order to compare the ability and advantage of the different generalised approaches. Two candidate functions (Richards, q-exponential) were modified, to guarantee that they pass through the point \( (d=0, h=1.30 \text{ m}) \) to prevent negative height estimates for small trees and/or to guarantee a good estimation for small trees. In this paper four different models of height-diameter equations were selected as candidate functions to model the generalised height-diameter relationship (Lundqvist, 1957; Richards, 1959; Ratkowsky and Reedy, 1986; Rupšys and Petrauskas, 2010). The three-parameter Korf (Lundqvist, 1957) model (Eq. 1), the three-parameter Chapman-Richards model (Richards, 1959) (Eq. 2), the three-parameter modified logistic model (Ratkowsky and Reedy, 1986) (Eq. 3), and new developed four-parameter q-exponential model (Eq. 4)

\[
h = \beta_0 e^{-\beta_d d^{\beta_2}},
\]

\[
h = 1.3 + \beta_0 \left(1 - e^{-\beta_d d^{\beta_2}}\right)^{\beta_3},
\]

\[
h = \frac{\beta_0}{1 + \beta_d d^{\beta_2}},
\]

\[
h = 1.3 + \beta_0 \left(1 - \beta_2 (1 - \beta_3 d^{\beta_1})^{1 - \beta_1}\right)^{\beta_2},
\]

\[
[a] = \begin{cases} a, & \text{if } a \geq 0, \\ 0, & \text{if } a < 0. \end{cases}
\]

where \( \beta_0 - \beta_4 \) are parameters estimated from the data. These models were chosen because they have been found to perform better overall than many other height-diameter models. The parameter \( \beta_0 \) defined in Eqs. 1-4 was expanded with different alternatives of stand variables using nonlinear regression analysis over the stand and tree variables for all plots. Different combinations of stand variables were included. The parameter \( \beta_0 \) takes the following forms

(a) \( \beta_0 = \beta_0 \cdot A^{\alpha_1} \)

(b) \( \beta_0 = \beta_0 \cdot d^{\alpha_1}_0 \)

(c) \( \beta_0 = \beta_0 \cdot h^{\alpha_1}_0 \)

(d) \( \beta_0 = \beta_0 \cdot d^{\alpha_1}_0 \cdot h^{\alpha_2}_0 \)

Results and Discussion

The parameters of all models were estimated by the least squares estimate technique, using the estimation data set, and presented in Table 2. All parameters are highly significant (\( \alpha < 0.05 \)).
Numerical and graphical analyses of the residuals were used as criteria for comparing the height equations. The performance statistics of the height equations: the mean bias, \(B\), (mean percentage of bias, \(PB\)), the mean of absolute bias, \(AB\), (mean percentage of absolute bias, \(PAB\)), the Akaike’s Information Criteria, \(AIC\), and an adjusted coefficient of determination, \(\bar{R}^2\).

\[
B = \frac{1}{n} \sum_{i=1}^{n} (y_i - \hat{y}_i), \quad PB = \frac{1}{n} \sum_{i=1}^{n} \left( \frac{\hat{y}_i - y_i}{y_i} \right) \cdot 100, \quad (9)
\]

\[
AB = \frac{1}{n} \sum_{i=1}^{n} |y_i - \hat{y}_i|, \quad PAB = \frac{1}{n} \sum_{i=1}^{n} \left( \frac{|\hat{y}_i - y_i|}{y_i} \right) \cdot 100, \quad (10)
\]

\[
AIC = n \ln(RSS) + 2p, \quad RSS = \sum_{i=1}^{n} (y_i - \hat{y}_i)^2, \quad (11)
\]

\[
\bar{R}^2 = 1 - \frac{1}{n-p} \sum_{i=1}^{n} (y_i - \bar{y})^2, \quad (12)
\]

where \(n\) is the total number of observations used to fit the height, \(p\) is the number of model parameters, \(y_i\), \(\hat{y}_i\), and \(\bar{y}\) are the measured, estimated and average values of the dependent variable (height), respectively. The \(AIC\) can generally be used for the identification of an optimum model in a class of competing models (Akaike, 1974). The first term on the
right hand side of AIC equation is a measure of the lack-of-fit of the chosen model, while the second term measures the increased unreliability of the chosen model due to the increased number of model parameters.

The results of goodness of fit statistics for all models applied to the both estimation and validation data sets are summarized in Table 3. In general, height models account for at least 46% of the variation in height (Table 3). For all diameters, it seems that any of the four models could be used as the base model. Fit characteristics (B, PB, AB, PAB, AIC, $R^2$) of the q-exponential model (Eq. 4) with stand variables defined by Eqs. 5-8 gave better results than the other models used here. In terms of all fitness statistics used, the q-exponential height model defined by Eqs. 4 and 8 appears to best predict height for Scots pine trees.

The final step in evaluating any biases in the various models involved visual examinations of residuals against the predicted values and lowess. Figure 1 shows the residuals plotted against predictions of height for models defined by Eqs. 1 and 5, Eqs. 2 and 6, Eqs. 3 and 7, and Eqs. 4 and 8, respectively, and lowess. Graphical diagnostics of residuals and lowess for the height predictions indicated that the residuals of all models are distributed very similar (Figure 1).

Conclusions

The q-exponential function was utilized to model the total tree height.

The results demonstrated that for modelling the height, the q-exponential models defined by Eqs. 4 and 5-8 showed the best fit for Scots pine trees.

The inclusion of the three stand variables results in a large improvement in the model fit relative to the models based on diameter alone, as can be seen through comparison of the models’ AIC (Table 2).

The inclusion of mean diameter and mean height in the height-diameter models provided significantly better fits of height than those using only diameter and alone stand variable (Table 2).

Table 3. Estimation goodness of fit statistics for all models applied to the estimation and validation data sets

<table>
<thead>
<tr>
<th>Models</th>
<th>Estimation</th>
<th>Validation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eq.1</td>
<td>B (PB) 0.0038 (-2.6532) 2.5623 (12.8757) 82992.3 0.4594 -0.0909 (-2.9135) 2.5001 (12.5350) 59146.1 0.4701</td>
<td></td>
</tr>
<tr>
<td>Eq.1&amp;(a)</td>
<td>B (PB) -0.0193 (-2.3651) 2.4633 (12.4516) 82382.9 0.4977 -0.1521 (-3.0811) 2.4149 (12.1937) 58852.7 0.5015</td>
<td></td>
</tr>
<tr>
<td>Eq.1&amp;(b)</td>
<td>B (PB) 0.0043 (-2.4193) 2.3818 (11.9674) 82008.1 0.5227 0.0960 (-2.6633) 2.3311 (11.6606) 58422.1 0.5374</td>
<td></td>
</tr>
<tr>
<td>Eq.1&amp;(c)</td>
<td>B (PB) -0.0171 (-0.6785) 1.1259 (5.9202) 72222.3 0.8739 -0.0393 (-0.7218) 1.2353 (5.9913) 51572.4 0.8695</td>
<td></td>
</tr>
<tr>
<td>Eq.1&amp;(d)</td>
<td>B (PB) 0.0064 (-0.4164) 1.0603 (5.1124) 70304.3 0.9028 0.0057 (-0.4109) 1.0775 (5.1724) 50196.2 0.8988</td>
<td></td>
</tr>
<tr>
<td>Eq.2</td>
<td>B (PB) 0.0003 (-2.7259) 2.5483 (12.8029) 82867.6 0.4634 -0.0948 (-2.9940) 2.4865 (12.4585) 59101.6 0.4743</td>
<td></td>
</tr>
<tr>
<td>Eq.2&amp;(a)</td>
<td>B (PB) 0.0021 (-2.5711) 2.4614 (12.4204) 82348.8 0.5000 -0.1345 (-3.0302) 2.4055 (12.1190) 58786.6 0.5052</td>
<td></td>
</tr>
<tr>
<td>Eq.2&amp;(b)</td>
<td>B (PB) -0.0026 (-2.4704) 2.3792 (11.9493) 81989.3 0.5239 -0.1038 (-2.7239) 2.3269 (11.6308) 58409.0 0.5385</td>
<td></td>
</tr>
<tr>
<td>Eq.3</td>
<td>B (PB) -0.0001 (-0.6379) 1.2179 (5.9237) 72195.2 0.8743 -0.0231 (-0.6861) 1.2355 (5.9752) 51562.4 0.8697</td>
<td></td>
</tr>
<tr>
<td>Eq.3&amp;(a)</td>
<td>B (PB) 0.0004 (-0.4632) 1.0483 (5.0446) 70203.4 0.9042 0.0028 (-0.4485) 1.0651 (5.0950) 50125.7 0.9001</td>
<td></td>
</tr>
<tr>
<td>Eq.3&amp;(b)</td>
<td>B (PB) 0.0005 (-2.7268) 2.5492 (12.8072) 82877.7 0.4626 -0.0945 (-2.9768) 2.4885 (12.4832) 59119.9 0.4736</td>
<td></td>
</tr>
<tr>
<td>Eq.3&amp;(c)</td>
<td>B (PB) 0.0009 (-2.5606) 2.4626 (12.4385) 82359.6 0.4993 -0.1343 (-3.0132) 2.4626 (12.4385) 58794.8 0.5044</td>
<td></td>
</tr>
<tr>
<td>Eq.4</td>
<td>B (PB) -0.0021 (-2.4540) 2.3805 (11.9669) 82001.3 0.5231 -0.1024 (-2.6988) 2.3194 (11.6580) 58417.3 0.5378</td>
<td></td>
</tr>
<tr>
<td>Eq.4&amp;(a)</td>
<td>B (PB) 0.0000 (-2.7297) 2.5467 (12.7963) 82858.3 0.4642 -0.0958 (-3.0018) 2.4848 (12.4499) 59099.4 0.4746</td>
<td></td>
</tr>
<tr>
<td>Eq.4&amp;(b)</td>
<td>B (PB) 0.0009 (-2.5750) 2.4603 (12.4173) 82342.4 0.5005 -0.1353 (-3.0368) 2.4036 (12.1120) 58784.2 0.5055</td>
<td></td>
</tr>
<tr>
<td>Eq.4&amp;(c)</td>
<td>B (PB) -0.0027 (-2.4706) 2.3772 (11.9408) 81972.8 0.5250 -0.1047 (-2.7268) 2.3223 (11.6124) 58397.0 0.5396</td>
<td></td>
</tr>
<tr>
<td>Eq.4&amp;(d)</td>
<td>B (PB) 0.0000 (-0.6368) 1.2174 (5.9212) 72196.3 0.8743 -0.0228 (-0.6842) 1.2352 (5.9757) 51563.6 0.8697</td>
<td></td>
</tr>
</tbody>
</table>

The best values of the performance statistics for all scenarios of stand variables are in bold.
Figure 1. Residuals for the height-diameter model and lowess

References


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Assessment of Fish Processing Wastes for the Improvement of Soil Properties

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Aleksandras Stulginskis University, Lithuania

Abstract

Two soils differing in pH value and in the texture have been taken for the experiment settlement – medium heavy loam and sandy loam. In order to examine the possibilities of fish and rape processing wastes to improve soil properties, the methodology was elaborated and the experiment started. Thus, after the preparation of fish bones, their powder was obtained and when mixed with the soil, it was placed into the special vegetative pots of 5 l in volume up to the thickness of 25 cm. The experiment has designed in 4 variants and 6 replications. The results obtained show that fish bones application has significantly influenced the increase of available phosphorus, mineral, nitrate and ammonium nitrogen content in the both experimentally tested soils. In general, the noticeable higher positive impact of fish bones application was observed in the sandy loam (forest) soil. The fish bones application have had positive effect on the content of available potassium, calcium and available sulfur in the medium heavy loam soil as well as on the content of available potassium, calcium, magnesium, total nitrogen and available sulfur in the sandy loam soil. In the case of magnesium and total nitrogen content, the increase was significant. Also, the fish bones application has decreased the acidity of sandy loam (forest) soil by 0.1–0.3 unit. Neither the amount nor the time of fish bones application didn’t show any noticeable impact on soil pH value, magnesium and total nitrogen content in medium heavy loam soil. The organic carbon content remained unchanged both in medium heavy loam and sandy loam soils. Fish bones application has significantly influenced the increase of microbiota abundance in medium heavy loam (agricultural) as well as in sandy loam (forest) soils. However, the significantly by 2-9 times higher abundance was estimated in amended agricultural soils. Microbial biomass carbon and nitrogen in tested soils have been increasing along with fish bones application but not so drastically as microbial abundance. In amended agricultural soils the microbial biomass nitrogen was more than 2 times and carbon more then 3 times higher than in forest soils.

Key words: soil, fish bones, nutrient availability, microbial abundance.

Introduction

Nowadays a food production without waste is very important, therefore, it is necessary to find appropriate utilization ways of waste products. In general, many organic wastes contain nutrients and organic matter that may benefit plant growth and soil productivity. Recycling these materials onto land captures nutrients that would otherwise be lost, and helps sustain our resource base.

Fish waste management has been one of the problems having the greatest impact on the environment in recent years. Due to its high organic content, fish waste is often classified as a certified (prescribed) waste which is even more costly to dispose (Jespersen et al., 2000). Nevertheless, treated fish waste has found many practical applications among which the most important are animal feed, biodiesel/biogas, dietary products (chitosan), natural pigments (after extraction), food-packaging applications (chitosan), cosmetics (collagen), enzyme isolation, Cr immobilisation, soil fertiliser and moisture maintenance (hydrolysates) in foods (Arvanitoyannis and Kassaveti, 2008).

The fisheries waste is high in nitrogen and phosphorus, and also contains important trace elements making it an excellent broad-based organic fertilizer. A numerous researches over the years have showed the efficiency of fish by-products application for crop production and soil improvement, either singly or in combination with other amendments (El-Tarabily et al., 2003; Walworth et al., 2003; Abbasi et al., 2004; Knucky et al., 2004; Abbasi et al., 2006; Quilty J. and Cattle S., 2010). Some of these products may potentially help to improve or sustain soil health at relatively low application rates, through stimulating biological activity, enhancing nutrient and carbon cycling in the soil and potentially increasing the amount of organic carbon in the soil (Mondini et al., 2008; Rathore et al., 2009).

The aim of this work is to identify any changes to soil characteristics (pH level, nutrient availability) and soil microbiota (abundance, microbial biomass carbon and nitrogen) as resulting from the fish bones application rates and time.

Material and methods

Two soils differing in pH value and in the texture have been taken for the experiment settlement – medium loam and sandy loam. This solution was based on the presumption that the transformation of non-available mineral nutrients into available for the plants mineral nutrients differ depending on soil pH value. Foreseen soil amount necessary for the experiment was collected with steel auger from the upper 0-25 cm layer (humic horizon) in the arable and afforested land. Having received fish bones (T 681-5 VASKET Bein R1) they were dried at 105°C temperature and milled up to 1.5 mm size particles in order to get suitable for the application fertilizer form. After the preparation procedure, the fish bones powder was mixed with the soil and placed into special vegetative pots of 5 l in volume up to the thickness of 25 cm. The experiment has been implemented in 4 variants and 6 replications.

Scheme of the fertilization with fish bones experiment

1. Control (without fish bones application)
2. 2.5 t ha⁻¹ (18 g of fish bones powder into the vegetative pot)
3. 4.5 t ha⁻¹ (32 g of fish bones powder into the vegetative pot)
4. 6.5 t ha⁻¹ (46 g of fish bones powder into the vegetative pot)
The vegetative pots with the soil and fish bones mixture have been stored at the different temperature regime: (1) first 30 days will be kept at 10°C degree, and (2) remaining 60 days - at 18°C degree. Simultaneously, some vegetative pots with the soil and fish bones mixture were kept at the 1-5°C temperature regime in order to estimate possible changes of nutrients in cold conditions corresponding winter season. The moisture of substrate (mixture) is 70% from the water holding capacity. It is planned to measure the changes of mineral nutrients in substrate three times: (1) 30 (one months), (2) 120 (four months) and (3) 360 days (twelve months) after the fish bones application. Chemical soil analyses were carried out by the appropriate conventional methods at the Agrochemical Research Laboratory of the Lithuanian Research Centre for Agriculture and Forestry.

Results and discussion

Before the experiment pH value of medium heavy loam soil was 6.7 (close to neutral) and after the one month of fish bones application it practically didn’t change (Table 1). However, after the four months of fish bones application some changes in soil pH value have been apparent but they were not significant. It was found that the value of soil pH has changed by 0.05 unit after the application 2.5 and 4.5 t ha⁻¹ of fish bones and by 0.15 unit – after the application 6.5 t ha⁻¹ of fish bones. Before the experiment a sandy loam soil was strongly acid (pH₉Cl 4.2). After one month of the experiment it was found that soil acidity decreased by 0.1 unit when 2.5 and 4.5 t ha⁻¹ of fish bones applied and by 0.3 unit after the application 6.5 t ha⁻¹ of fish bones (Table 5). After four months of the experiment pH value of the sandy loam soil was found at the same level as it was one month after the fish bones application. However, pH value of sandy loam soil increased by 0.2 in the case when 4.5 t ha⁻¹ of fish bones applied and thus has showed the same effect as it was obtained with the 6.5 t ha⁻¹ of fish bones application.

Before the experiment a medium heavy loam soil contained 88-100 mg kg⁻¹ of available phosphorus (P₂O₅) and 50 mg kg⁻¹ of available potassium (K₂O). After one month of fish bones application the content of available phosphorus significantly increased and that directly depends on the fish bones rate that was applied (Table 2). The content of available phosphorus increased in 6.72 times after the application 2.5 t ha⁻¹ of fish bones and it has reached even 1376 mg kg⁻¹ when the rate of fish bones have been increased up till 6.5 t ha⁻¹. Although a tendency of some further increase in available phosphorus content was estimated four months after of fish bones application, it was insignificant in comparison with the effect estimated one month after fish bones application. Having analyzed fish bones application impact on available potassium in the medium heavy loam soil it was found a considerable increase of this element both one and four months after fish bones application. Respectively, one month after fish bones application the content of available potassium increased by 8.2-30.6 % and four months after application by 13.2-15.1 % in comparison with control variant. The maximum potassium increase (18.9 %) four months after fish bones application was found in the case when the maximum rate of 6.5 t ha⁻¹ have been applied. Nevertheless, even taking into account this considerable increase, it corresponds only to group II (small amount) according to the Lithuanian classification of soil richness in available potassium.

### Table 1. The impact of fish bones application on the pH value change in different textured soils

<table>
<thead>
<tr>
<th>Rate of fish bones applied into the soil</th>
<th>In medium heavy loam</th>
<th>Soil pH₉Cl</th>
<th>In sandy loam</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>After 1 month</td>
<td>After 4 months</td>
<td>After 1 month</td>
</tr>
<tr>
<td>Control</td>
<td>6.70</td>
<td>6.70</td>
<td>4.2</td>
</tr>
<tr>
<td>2.5 t ha⁻¹</td>
<td>6.70</td>
<td>6.75</td>
<td>4.3</td>
</tr>
<tr>
<td>4.5 t ha⁻¹</td>
<td>6.70</td>
<td>6.75</td>
<td>4.3</td>
</tr>
<tr>
<td>6.5 t ha⁻¹</td>
<td>6.65</td>
<td>6.85</td>
<td>4.5</td>
</tr>
<tr>
<td>LSD₀₅</td>
<td>0.113</td>
<td>0.161</td>
<td>0.113</td>
</tr>
</tbody>
</table>

Before the experiment a sandy loam soil contained 45-51 mg kg⁻¹ of available phosphorus (P₂O₅) and 51-52 mg kg⁻¹ of available potassium (K₂O). In both cases it is considered as very poor conditions according to the Lithuanian classification of soil richness in available phosphorus and potassium. However, it was found that content of available phosphorus significantly increased in all cases after fish bones application and that directly depends on the rate of fish bones that was applied (Table 3). Respectively, one month after fish bones application the content of

<table>
<thead>
<tr>
<th>Rate of fish bones applied into the soil</th>
<th>Content of available phosphorus (P₂O₅) in the soil mg kg⁻¹</th>
<th>Content of available potassium (K₂O) in the soil mg kg⁻¹</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>After 1 month</td>
<td>After 4 months</td>
</tr>
<tr>
<td>Control</td>
<td>94,0</td>
<td>100,0</td>
</tr>
<tr>
<td>2.5 t ha⁻¹</td>
<td>726,0</td>
<td>763,0</td>
</tr>
<tr>
<td>4.5 t ha⁻¹</td>
<td>951,0</td>
<td>949,0</td>
</tr>
<tr>
<td>6.5 t ha⁻¹</td>
<td>1376,0</td>
<td>1597,0</td>
</tr>
<tr>
<td>LSD₀₅</td>
<td>287,29</td>
<td>419,21</td>
</tr>
</tbody>
</table>

Before the experiment a sandy loam soil contained 45-51 mg kg⁻¹ of available phosphorus (P₂O₅) and 51-52 mg kg⁻¹ of available potassium (K₂O). In both cases it is considered as very poor conditions according to the Lithuanian classification of soil richness in available phosphorus and potassium. However, it was found that content of available phosphorus significantly increased in all cases after fish bones application and that directly depends on the rate of fish bones that was applied (Table 3). Respectively, one month after fish bones application the content of
available phosphorus increased by 334.5-787 mg kg\(^{-1}\) and four months after application – 364-568.5 mg kg\(^{-1}\). Thus, after the fish bones application sandy loam soil richness in available phosphorus corresponds to group V (very high amount).

Table 3. The impact of fish bones application on the available phosphorus (P\(_2\)O\(_5\)) and available potassium (K\(_2\)O) content changes in sandy loam soil

<table>
<thead>
<tr>
<th>Rate of fish bones applied into the soil</th>
<th>Content of available phosphorus (P(_2)O(_5)) in the soil mg kg(^{-1})</th>
<th>Content of available potassium (K(_2)O) in the soil mg kg(^{-1})</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>After 1 month</td>
<td>After 4 months</td>
</tr>
<tr>
<td>Control</td>
<td>47.0</td>
<td>54.0</td>
</tr>
<tr>
<td>2.5 t ha(^{-1})</td>
<td>381.5</td>
<td>364.0</td>
</tr>
<tr>
<td>4.5 t ha(^{-1})</td>
<td>487.0</td>
<td>519.5</td>
</tr>
<tr>
<td>6.5 t ha(^{-1})</td>
<td>834.0</td>
<td>568.5</td>
</tr>
<tr>
<td>LSD(_{0.05})</td>
<td>321.56</td>
<td>151.37</td>
</tr>
</tbody>
</table>

Having analyzed fish bones application impact on available potassium in the sandy loam soil it was found a considerable increase of this element both one and four months after fish bones application. Respectively, one month after fish bones application content of available potassium increased by 10-33 mg kg\(^{-1}\) and four months after application by 32.2-34.7 % in comparison with control variant. The maximum and significant potassium increase (48.8 %) four months after application was found in the case when the rate of 6.5 t ha\(^{-1}\) fish bones applied. Nevertheless, even taking into account this considerable increase, it corresponds only to group II (small amount) according to the Lithuanian classification of soil richness in available potassium.

The experimental data doesn’t show any determinant impact of fish bones application on soil organic carbon change both in medium heavy loam and sandy loam soils (Table 4). For instance, one month after fish bones application the content of organic carbon even slightly decreased (0.7-1.1 %) in medium heavy loam but it was not significant difference. On the contrary, in sandy loam soil, one month after fish bones application the content of organic carbon has slightly increased (3.5-4.5 %) but also it was not significant difference. Similarly, such the nonessential tendencies have been observed four months after the fish bones application both in heavy medium loam and sandy loam soils.

Table 4. The impact of fish bones application on the organic carbon content in medium heavy loam and sandy loam soils

<table>
<thead>
<tr>
<th>Rate of fish bones applied into the soil</th>
<th>Content of organic carbon in the soil % in medium heavy loam</th>
<th>Content of organic carbon in the soil % in sandy loam</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>After 1 month</td>
<td>After 4 months</td>
</tr>
<tr>
<td>Control</td>
<td>8.81</td>
<td>7.90</td>
</tr>
<tr>
<td>2.5 t ha(^{-1})</td>
<td>7.71</td>
<td>8.50</td>
</tr>
<tr>
<td>4.5 t ha(^{-1})</td>
<td>8.11</td>
<td>9.72</td>
</tr>
<tr>
<td>6.5 t ha(^{-1})</td>
<td>7.89</td>
<td>8.06</td>
</tr>
<tr>
<td>LSD(_{0.05})</td>
<td>0.712</td>
<td>1.890</td>
</tr>
</tbody>
</table>

Before the experiment a medium heavy loam soil contained 7748–7892 mg kg\(^{-1}\) of calcium and 652 mg kg\(^{-1}\) of magnesium. One month after fish bones application the content of calcium has slightly increased up to 8386–9202 mg kg\(^{-1}\) as dependent on the rate of fish bones has been applied. Similarly, four months after fish bones application the content of calcium increased up to 8376–9322 mg kg\(^{-1}\). However, there was no effect of fish bones application on magnesium content in medium heavy loam soil both one and four months after fish powder application (Table 5).

Table 5. The impact of fish bones application on calcium (Ca) and magnesium (Mg) content in medium heavy loam soil

<table>
<thead>
<tr>
<th>Rate of fish bones applied into the soil</th>
<th>Calcium (Ca) content in the soil mg kg(^{-1})</th>
<th>Magnesium (Mg) content in the soil mg kg(^{-1})</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>After 1 month</td>
<td>After 4 months</td>
</tr>
<tr>
<td>Control</td>
<td>7820</td>
<td>8044</td>
</tr>
<tr>
<td>2.5 t ha(^{-1})</td>
<td>8386</td>
<td>8376</td>
</tr>
<tr>
<td>4.5 t ha(^{-1})</td>
<td>8455</td>
<td>8780</td>
</tr>
<tr>
<td>6.5 t ha(^{-1})</td>
<td>9202</td>
<td>9322</td>
</tr>
<tr>
<td>LSD(_{0.05})</td>
<td>320.262</td>
<td>984.725</td>
</tr>
</tbody>
</table>

Before the experiment a sandy loam soil contained only 490 mg kg\(^{-1}\) of calcium (Ca) and 88 mg kg\(^{-1}\) of magnesium (Mg). It was found that content of calcium steady and significantly increased in all cases after fish bones application and that directly depends on the rate of fish bones that was applied (Table 6). Respectively, one month after fish bones application the content of calcium increased up to 1387–1583 mg kg\(^{-1}\) and four months after application – up to 873–1519 mg kg\(^{-1}\). Nevertheless, four months after fish bones application it was estimated some calcium content decrease in comparison with the content of calcium one month after fish bones application. Probably, such a tendency is connected to the high acidity level (pH 4.2-4.5) of sandy loam soil. Having analyzed the impact of fish bones application on magnesium content in the sandy loam soil it was found a considerable increase of this element both one
and four months after fish bones application (Table 6). Respectively, one month after fish powder application content of available potassium increased by 30%–57% and four months after application – by 14%–25% in comparison with control variant.

Table 6. The impact of fish bones application on calcium (Ca) and magnesium (Mg) content in sandy loam soil

<table>
<thead>
<tr>
<th>Rate of fish bones applied into the soil</th>
<th>Calcium (Ca) content in the soil mg kg⁻¹</th>
<th>Magnesium (Mg) content in the soil mg kg⁻¹</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>After 1 month</td>
<td>After 4 months</td>
</tr>
<tr>
<td>Control</td>
<td>493</td>
<td>547</td>
</tr>
<tr>
<td>2.5 t ha⁻¹</td>
<td>1387</td>
<td>873</td>
</tr>
<tr>
<td>4.5 t ha⁻¹</td>
<td>1652</td>
<td>1204</td>
</tr>
<tr>
<td>6.5 t ha⁻¹</td>
<td>1583</td>
<td>1519</td>
</tr>
<tr>
<td>LSD₀.₀5</td>
<td>886.459</td>
<td>164.941</td>
</tr>
</tbody>
</table>

Before the experiment it was found 0.591–0.648% of total nitrogen and 45.98–47.71 mg kg⁻¹ of mineral nitrogen in a medium heavy loam soil. The experimental date have shown (Table 7) that in some cases the content of total nitrogen slightly decreased (by 0.03–0.04%). Even so, the mathematical-statistical analysis of nitrogen content doesn’t show any determinant impact of fish bones utilization in a medium heavy loam soil one and four months after the application. Having analyzed the impact of fish bones application on mineral nitrogen in medium heavy loam soil it was found positive effect both one and four months after fish bones application. Respectively, one month after fish bones application the content of mineral nitrogen has significantly increased from 90.13 up till 223.15 mg kg⁻¹ and four months after fish bones application – from 130.39 up till 321 mg kg⁻¹ in comparison with the control variant. In all cases such a tendency was strongly connected to the applied fish bones rate.

Table 7. The impact of fish bones application on total and mineral nitrogen content in medium heavy loam soil

<table>
<thead>
<tr>
<th>Rate of fish bones applied into the soil</th>
<th>Total nitrogen content in the soil %</th>
<th>Mineral nitrogen content in the soil mg kg⁻¹</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>After 1 month</td>
<td>After 4 months</td>
</tr>
<tr>
<td>Control</td>
<td>0.620</td>
<td>0.659</td>
</tr>
<tr>
<td>2.5 t ha⁻¹</td>
<td>0.620</td>
<td>0.668</td>
</tr>
<tr>
<td>4.5 t ha⁻¹</td>
<td>0.616</td>
<td>0.673</td>
</tr>
<tr>
<td>6.5 t ha⁻¹</td>
<td>0.617</td>
<td>0.655</td>
</tr>
<tr>
<td>LSD₀.₀5</td>
<td>0.046</td>
<td>0.052</td>
</tr>
</tbody>
</table>

Before the experiment it was found 0.137–0.128% of total nitrogen and 33.66 mg kg⁻¹ of mineral nitrogen in a sandy loam soil. One month after fish bones application, the content of total nitrogen slightly increased (by 0.03–0.05%) in comparison with the control variant (Table 8). Although four months after fish bones application the content of total nitrogen increased only by 0.03–0.04% when the rate of 2.5 and 4.5 t ha⁻¹ of fish bones utilized, it was found to be a significant increase. Having analyzed the impact of fish bones application on mineral nitrogen content in sandy loam soil it was estimated positive effect both one and four months after the fish bones utilization. Thus, one month after fish bones application the content of mineral nitrogen has significantly increased from 75.92 up till 212.03 mg kg⁻¹. Similarly, a significant increase of mineral nitrogen was found four months after fish bones application when 4.5 and 6.5 t ha⁻¹ utilized. In all cases this increase is strongly dependent on the applied fish bones rate.

Table 8. The impact of fish bones application on total and mineral nitrogen content in sandy loam soil

<table>
<thead>
<tr>
<th>Rate of fish bones applied into the soil</th>
<th>Total nitrogen content in the soil %</th>
<th>Mineral nitrogen content in the soil mg kg⁻¹</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>After 1 month</td>
<td>After 4 months</td>
</tr>
<tr>
<td>Control</td>
<td>0.133</td>
<td>0.142</td>
</tr>
<tr>
<td>2.5 t ha⁻¹</td>
<td>0.162</td>
<td>0.156</td>
</tr>
<tr>
<td>4.5 t ha⁻¹</td>
<td>0.184</td>
<td>0.178</td>
</tr>
<tr>
<td>6.5 t ha⁻¹</td>
<td>0.165</td>
<td>0.167</td>
</tr>
<tr>
<td>LSD₀.₀5</td>
<td>0.057</td>
<td>0.016</td>
</tr>
</tbody>
</table>

Before the experiment it was found 41.15–42.85 mg kg⁻¹ of nitrate nitrogen and 4.83–4.86 mg kg⁻¹ of ammonium nitrogen in a medium heavy loam soil. It was found that content of nitrate nitrogen consistently increased in all cases after fish bones application and that directly depends on the rate of fish bones that was applied (Table 9). Respectively, one month after fish bones application the content of nitrate nitrogen increased from 212% up till 522% and four months after application – from 143% up till 351%. Having analyzed the impact of fish bones application on ammonium nitrogen content it was estimated a significant increase of this compound by 1.18–3.84 mg kg⁻¹ one month after the fish bones utilization in medium heavy loam soil. A strong correlation has been found between ammonium nitrogen content in the soil and fish bones rate. The slightly increase of ammonium nitrogen was estimated also four months after the fish bones application in comparison with the control variant. On the other hand, four months after the
fish bones application a significant decrease of ammonium nitrogen content was observed in comparison with the amount of ammonium nitrogen that was estimated one month after the fish bones utilization.

Table 9. The impact of fish bones application on nitrate (NO$_3^-$) and ammonium nitrogen (NH$_4^+$) content in medium heavy loam soil

<table>
<thead>
<tr>
<th>Rate of fish bones applied into the soil</th>
<th>Nitrate (NO$_3^-$) nitrogen content in the soil (mg kg$^{-1}$)</th>
<th>Ammonium (NH$_4^+$) nitrogen content in the soil (mg kg$^{-1}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>After 1 month</td>
<td>After 4 months</td>
</tr>
<tr>
<td>Control</td>
<td>42.0</td>
<td>91.02</td>
</tr>
<tr>
<td>2.5 t ha$^{-1}$</td>
<td>130.95</td>
<td>220.9</td>
</tr>
<tr>
<td>4.5 t ha$^{-1}$</td>
<td>200.06</td>
<td>263.75</td>
</tr>
<tr>
<td>6.5 t ha$^{-1}$</td>
<td>261.31</td>
<td>410.7</td>
</tr>
<tr>
<td>LSD05</td>
<td>8.508</td>
<td>0.088</td>
</tr>
</tbody>
</table>

Before the experiment it was found 30.13–34.7 mg kg$^{-1}$ of nitrate nitrogen and 3.53–3.75 mg kg$^{-1}$ of ammonium nitrogen in sandy loam soil. It was found that content of nitrate nitrogen consistently increased both one and four months after the fish bones application (Table 10). Thus, one month after the fish bones application the content of nitrate nitrogen has increased from 75.62 up till 191.47 mg kg$^{-1}$. Four months after the fish bones application the content of nitrate nitrogen significantly increased when 4.5 and 6.5 t ha$^{-1}$ fish bones have been applied. Having analyzed the impact of fish bones application on ammonium nitrogen content it was estimated a significant increase of this compound one month after the fish bones utilization in sandy loam soil. A significant increase by 3.41–20.56 mg kg$^{-1}$ was estimated when the rate 4.5 and 6.5 t ha$^{-1}$ of fish bones have been applied. Four months after the fish bones application the analoguous tendency observed.

Table 10. The impact of fish bones application on nitrate (NO$_3^-$) and ammonium nitrogen (NH$_4^+$) content in sandy loam soil

<table>
<thead>
<tr>
<th>Rate of fish bones applied into the soil</th>
<th>Nitrate (NO$_3^-$) nitrogen content in the soil (mg kg$^{-1}$)</th>
<th>Ammonium (NH$_4^+$) nitrogen content in the soil (mg kg$^{-1}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>After 1 month</td>
<td>After 4 months</td>
</tr>
<tr>
<td>Control</td>
<td>32.42</td>
<td>136.60</td>
</tr>
<tr>
<td>2.5 t ha$^{-1}$</td>
<td>108.04</td>
<td>196.25</td>
</tr>
<tr>
<td>4.5 t ha$^{-1}$</td>
<td>135.23</td>
<td>306.10</td>
</tr>
<tr>
<td>6.5 t ha$^{-1}$</td>
<td>223.89</td>
<td>449.30</td>
</tr>
<tr>
<td>LSD05</td>
<td>27.303</td>
<td>102.492</td>
</tr>
</tbody>
</table>

Before the experiment it was found 3.6 mg kg$^{-1}$ (poor level) of available sulfur in medium heavy loam soil. One month after the fish bones application some slightly increase in the content of sulfur (by 0.1–0.5 mg kg$^{-1}$) observed. The much more significant increase of sulfur content estimated four months after the fish bones application (from 3.55 up till 15.9 mg kg$^{-1}$) but the only statistically significant increase was found when 6.5 t ha$^{-1}$ of fish bones has been utilized. Before the experiment it was found only 0.8 mg kg$^{-1}$ (very poor level) of available sulfur in sandy loam soil. One month after the fish bones application some changes observed but they were very much irregular. Four months after the fish bones applied, the content of available sulfur significantly increased from 18.33 up till 26.38 mg kg$^{-1}$ in comparison with the control variant. It is worthy to note that all soils containing > 12.0 mg kg$^{-1}$ of available sulfur are considered to be rich in sulfur according to the Lithuanian natural conditions.

The fish bones application has significantly influenced the increase in microbiota abundance in tested soils (Table 11). However, the higher mean total abundance of microbiota was in agricultural soils. It was estimated, that the abundance of microbiota have been increasing along with fish bones application and in agricultural soils it comprised from 997.6 to 11259.5 thousand CFU g$^{-1}$. Though, the mean total abundance of microbiota in amended forest soils was significantly (p<0.05) by 2–9 times lower than in amended agricultural soils. Even though, the abundance of microbiota have been also increasing along with fish bones application the mean microbiota abundance here comprised from 498.8 to 1316.7 thousand CFU g$^{-1}$.

Table 11. The impact of fish bones application on microbiota mean total abundance in tested soils

<table>
<thead>
<tr>
<th>Rate of fish bones applied into the soil</th>
<th>Abundance of microbiota thousand CFU g$^{-1}$ (DM)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>In medium heavy loam after 4 months</td>
</tr>
<tr>
<td>Control</td>
<td>997.6 ± 47.1</td>
</tr>
<tr>
<td>2.5 t ha$^{-1}$</td>
<td>2526.1 ± 272.4</td>
</tr>
<tr>
<td>4.5 t ha$^{-1}$</td>
<td>5932.6 ± 472.3</td>
</tr>
<tr>
<td>6.5 t ha$^{-1}$</td>
<td>11259.5 ± 127.3</td>
</tr>
</tbody>
</table>

Note: in the tables 11 and 12, the average data of standard nutrient mediums is presented. Standard errors of means (n = 6) are given in the table.

The mean values for microbial biomass C were 59.2 and 102.0 µg C g$^{-1}$ in forest, thus, 136.1 and 321.2 µg C g$^{-1}$ in agricultural soils (Table 12). The results of the soil microbial biomass analysis indicate that the amended agricultural soils contained significantly 2-3 times highest microbial biomass C than in amended forest soils. The same tendencies could be determined estimating the microbial biomass nitrogen in tested soils. However, the differences were not
considerably high. The mean values for microbial biomass N ranged from 8.2 to 14.2 µg N g⁻¹ in forest, and from 12.4 to 29.2 µg N g⁻¹ in agricultural soils.

### Table 12. The impact of fish bones application on microbiota biomass carbon and nitrogen mean concentrations in tested soils

<table>
<thead>
<tr>
<th>Rate of fish bones applied into the soil</th>
<th>Microbiota biomass carbon µg C g⁻¹ after 4 months</th>
<th>Microbiota biomass nitrogen µg N g⁻¹ after 4 months</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>In medium heavy loam</td>
<td>In sandy loam</td>
</tr>
<tr>
<td>Control</td>
<td>136.1 ± 4.8</td>
<td>59.2 ± 2.1</td>
</tr>
<tr>
<td>2.5 t ha⁻¹</td>
<td>239.2 ± 8.0</td>
<td>77.2 ± 2.6</td>
</tr>
<tr>
<td>4.5 t ha⁻¹</td>
<td>264.4 ± 9.2</td>
<td>91.2 ± 3.2</td>
</tr>
<tr>
<td>6.5 t ha⁻¹</td>
<td>321.2 ± 9.3</td>
<td>102.0 ± 3.6</td>
</tr>
</tbody>
</table>

### Conclusions

The fish bones application has significantly influenced the increase of available phosphorus, mineral, nitrate and ammonium nitrogen content in the both experimentally tested soils. In general, the noticeable higher positive impact of fish bones application was observed in the sandy loam (forest) soil.

The fish bones application have had positive effect on the content of available potassium, calcium and available sulfur in the medium heavy loam soil as well as on the content of available potassium, calcium, magnesium, total nitrogen available and sulfur in the sandy loam soil. In the case of magnesium and total nitrogen content, the increase was significant. Also, the fish bones application has decreased the acidity of sandy loam (forest) soil by 0.1—0.3 unit.

Neither the amount nor the time of fish bones application didn’t show any noticeable impact on soil pH value, magnesium and total nitrogen content in medium heavy loam soil. The organic carbon content remained unchanged both in medium heavy loam and sandy loam soils.

Fish bones application has significantly influenced the increase in microbiota abundance in medium heavy loam (agricultural) as well as in sandy loam (forest) soils. However, the significantly by 2–9 times higher abundance was estimated in amended agricultural soils.

Microbial biomass carbon and nitrogen in tested soils have been increasing along with fish bones application but not so drastically as microbial abundance. In amended agricultural soils the microbial biomass nitrogen was more than 2 times and carbon more than 3 times higher than in forest soils.

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### References


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Hydraulic Geometry of the River Neris for the Assessment of Hydrokinetic Resources

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Aleksandras Stulginskis University, Lithuania

Abstract
Stage, discharge, flow velocity, and flow cross-section area data of the Lithuanian Hydrometeorological Service gauging (hydrometric) stations (GS) was used for the assessment of hydrokinetic energy resources (on the basis of the Neris river case). Close correlation of water level, discharge, velocity, and cross-section relations was identified during the investigations whereas GS water flow velocity histograms were compiled according to multi annual daily discharge curves and mean cross-sectional velocities as well as discharge relationship. The histograms are based on theoretical probability distributions and data validation tests. The best compliance is that of extreme value distribution. Hydraulic and geometric characteristics of the river flow, defined by the hydrological method, were compared with the results obtained by the hydraulic model (HEC-RAS). The compliance determined was valid. Transposition of the relation among flow velocity, bed cross-section area, depth of the river and the discharge over the length of the river is not possible for the assessment of hydropower resources due to the poor correlation of the data. Hydraulic simulation, using the digital terrain model (DTM) of the river bathymetry, is the main and the most precise method to assess the resources of hydrokinetic energy and select the most efficient location for the generation of hydropower whereas field measurements bear significance only for validation of the data.

Introduction
Hydropower resources of Lithuanian rivers, when potential energy is used (i.e. related to damming of a river), have been assessed. In addition, conventional hydropower technologies are matured and in power market; such energy output has a substantial basis (Jablonskis, 2005). Despite the existing river power resources that have not been used so far, it is more difficult for this conventional hydropower to develop due to environmental restrictions, namely prohibitions to dam rivers (Jablonskis et al., 2007; Punys et al., 2010). One of the solutions would be to tap damless technologies, based on the use of free flow velocity energy (hydrokinetic, subsequently HK), when producing electricity in the flowing water, i.e. a river or the other current of water. However, such riverine hydrokinetic power technologies have had neither industrial nor commercial value up to now (Khan et al., 2008). The reason for insignificant exploitation of HK resources is the lack of effective technologies and low capacity turbines operating in currents of rivers, namely from several to several hundred kW (Verdant..., 2006). According to the prediction of power market analytics, the situation is supposed to change basically after 15-20 years because the perspective predicted was the same as that of wind power (Johnson et al., 2010).

HK power resources were assessed in Canada in 2010 (Assessment..., 2010) and in the USA in 2012 (Assessment..., 2012). Instead of rivers, HK resources of tidal flow were estimated in Sweden and Norway (Grabbe et al., 2009; Lalander et al., 2013) whereas in Lithuania HK resources have not been assessed for any single river.

As Khan et al. (2008) highlight, spatial and temporal characteristics of discharge, depth of rivers, cross section areas of beds, water uses, and requirements of ecosystems are crucial to HK energy assessment, whereas basis of quantitative river data are not properly prepared for HK energy analysis. Therefore, the methods for the analysis of the data must be developed. Lalander et al. (2013) point out that a special attention is paid to HK technology more frequently than to the assessment of resources within the area. In spite of the fact that detail databases of rivers exist, the relationship between current velocity and discharge is seldom known.

Two ways to define HK resources can be distinguished, i.e. hydrological, when formulae of conventional potential or kinetic power are used, and hydraulic or hydrodynamic modelling (numerical, when the formula of kinetic power is used).

The hydrological method to define HK energy resources, based on the data of standard measurements of the river within hydrological network (namely, discharge, slope, velocity) is simple and reliable. On the other hand, it is complicated to integrate data over the length of the river, i.e. to assess the power of flow with regard to the area of the cross-section. Therefore, when assessing HK energy resources of the USA rivers, the ordinary formula of potential power instead of the kinetic power formula based on stream velocity (Assessment..., 2012), i.e. theoretical hydraulic power of river flow, using data bases of river standard discharge and water surface slope, was calculated. The technically recoverable HK resources were calculated, having entered reduction coefficient for the theoretical resources. The results are presented in the interactive atlas of river HK energy. In Canada, the first phase of evaluating HK energy has been initiated. Hydrological data of rivers in the country as well as suitability for hydrological methodologies to define HK resources are being analyzed (Assessment..., 2010).

When applying the hydraulic method, the expression of the HK power used is based on flow velocities. The change of flow velocity in the stretch of the river bed is simulated on the basis of initial data of discharge and bathymetry. HK resources in the USA, Alaskan rivers, were modelled with one-dimensional, (Previsic et al., 2008), two-dimensional, and three dimensional models (Toniolo et al 2010; Toniolo, 2012) while two-dimensional and three-dimensional models were employed in Sweden (Grabbe et al., 2009). In Lithuania, one-dimensional hydraulic model was used to define the theoretical HK energy resources of the river Neris (Punys et al., 2013).

No precise data, concerning morphometric parameters, roughness of open channels, and characteristics of water flow velocity, which determine dynamics of river flow, is found in Lithuania. Upon the initiative of Environmental...
Protection Agency (EPA), digital models of river beds and valley topography were developed (Punys et al., 2013). Gauging of discharge and water levels is constantly performed. However, it does not provide sufficient data for the assessment of HK resources along the rivers, in sites of interest. Discharge is defined by standard methods that are employed to gauge stream velocity. Then correlation of water velocity-discharge or current cross-section area is defined and afterwards HK energy of the river is calculated.

**The aim of the research** is to assess the main geometric and hydraulic characteristics of the Neris river flow on the basis of standard GS measurements, applying the hydrological method to define HK energy resources.

The following objectives were raised:
- To review the theoretical basis of HK energy as well as hydraulic and morphometric characteristics of the flow, essential for its evaluation;
- To collect historic hydrometric data in GS;
- To investigate the correlation of flow velocity, cross-section area, and the discharge; draw up histograms of flow velocities;
- Compare hydraulic and morphometric characteristics of flow, defined by hydrological and hydraulic methods;
- Assess the theoretical HK energy resources at GS.

**Object and research methods**

Research object is the largest Nemunas tributary – the Neris river, the total length of which is 510 km, 235 km out of which are located in the territory of Lithuania. The area of the basin reaches almost 25,000 km², 14,000 km² fall within the borders of Lithuania. The river part in the area of Lithuania was investigated. Discharge gradually increases over the river length, in the mouth it reaches 176 m³/s. Neris is considered to be the river of plains, the mean slope in Lithuania is 32 cm/km, it is free flowing stream. The biggest tributaries of the Neris in Lithuania are Zeimena (Q=27 m³/s) and Sventoji (Q=56 m³/s). Vilnia (Q=4.7 m³/s), Voke (Q=4.3 m³/s), Muse (Q=2.5 m³/s) and other 19 smaller rivers join the river.

GS data (table 1) of Lithuanian Hydrometeorological Service, concerning water level, discharge, velocity, and flow cross-section area was used in the research. Current velocity was gauged by current meter whereas for comparison of measurements recently acoustic velocity devices have been used.

### Table 1. Neris GS and data used in the study

<table>
<thead>
<tr>
<th>GS</th>
<th>Distance from the mouth, km</th>
<th>Area of the catchment, km²</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Stage-discharge Q=f(H), flow velocity - discharge v=f(Q), cross-section area - discharge A=f(Q) relationships</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Gauge period</td>
</tr>
<tr>
<td>Neris at Buivydziai</td>
<td>226</td>
<td>11,100</td>
<td>1966-1974</td>
</tr>
<tr>
<td>Neris at Vilnius</td>
<td>165</td>
<td>15,200</td>
<td>1923-1974</td>
</tr>
<tr>
<td>Neris at Jonava</td>
<td>39</td>
<td>24,600</td>
<td>1929-1974</td>
</tr>
</tbody>
</table>

According to World Meteorological Organization (WMO, 2010), normal, logarithmic normal, gamma, Weibull, generalized extreme values (GEV), Gumbel etc. distributions are used for the analysis of hydrological data probability distribution. STATISTICA and HYFRAN software was used to investigate the statistic performance. It was employed to undertake the analysis of distributions proposed by WMO.

When drawing up Q=f(H), v=f(Q) and A=f(Q) relationships, the methodology used is presented in WMO (2010). It is developed for open channel (not covered with ice) whereas unsteady flow (hysteresis) and prevailing hydraulic conditions (backwater, seasonal vegetation, ice phenomena, variation of roughness and channel geometry) were not analysed. The selected GS feature steady relationship between water stage and discharge.

To compile FDC, the data of daily flow was used while mean channel velocity was calculated using the relationship with flow. Histograms of a normal year flow velocities were compiled on the basis of measured channel velocity data relation with discharge – using multi annual FDC.

Numerical modelling data, defined using the programme HEC-RAS, was used to validate hydraulic and geometric parameters and their relations (Punys et al., 2013).

Hydrokinetic power of a cross-sectional flow area (P, kW), is calculated in the following way:

\[ P = \frac{1}{2} Q v^2 = \frac{1}{2} A v^3 , \]  

where: \( Q \) – discharge, m³/s; \( v \) – flow velocity, m/s; \( A \) – current cross-section area, m².

For practical application formula 1 is modified; the density of kinetic power (kW/m³), for 1 m² of flowing water cross-section area, can be given:
\[ D = \frac{P}{A} = \frac{1}{2} v^3. \] \hspace{1cm} (2)

In order to define the HK power extracted from a stream, one needs to know the velocity of flow, which is mostly determined by the discharge and channel geometry. They primary depend on the roughness of the channel and water surface slope. Flow velocity in the cross-section of the channel varies with regard to the depth. Horizontal fluctuation of velocity is difficult to define; moreover flow velocity ranges over time. The generalized mean annual velocity (according to the current depth and width) must be defined for the assessment of HK energy resources. When one knows the distribution of velocity at the channel cross-section, the mean distribution of power density can be easily calculated. Small changes in the local velocities will create significant changes in power density (equation 1), since power density is a function of the velocity cubed (Toniolo, 2012; Lanerolle et al, 2013).

Assessment of river flow geometric parameters in ungauged sites is the basis when evaluating HK energy. Empiric distribution function defined by Leopold and Maddock (1953), expressing the relationship of three hydraulic variables, namely velocity of flow \( v \), depth \( d \), and width \( w \), as well as discharge of mean or bankfull discharge \( Q \) (m\(^3\)/s), is applied for streams and open channels to analyze:

\[ v = kQ^m, d = cQ^f, w = aQ^h, \] \hspace{1cm} (3-5)

and the constants satisfy the conditions: \( m + f + b = 1 \); \( k, c, a = 1 \).

Results of research

Relationships of flow velocity, flow cross-section area, and discharge in GS

On the basis of gauged data of the river Neris at Buivydziai flow velocity, cross-section area on one part, and discharge, on other part relationship was carried out for the open channel (ice-free) (Fig. 1). Similar equations were established for Vilnius and Jonava GS.

Figure 1. Flow velocity, cross-section area and discharge rating curves fitted by the power function model for the Neris river at Buivydziai

A power function best reflects the relationship. It is close and robust. Though, degree 2 polynomial and logarithmic functions are also of good fit. Analogous results were identified during the analysis of discharge rating curves \( Q = f(H) \). Nevertheless, these curves, as intermediate results, are not provided in the article.

Flow duration curves

Above mentioned relationships were derived using the historical, quite long records of measured river flow, mean velocity and channel cross-section. However, there was the need to extend the constructed relations based on the last period of measurements. Figure 2 below exhibits the normalized FDC for the GS created from the past 25 year period of flow record time series (1986-2010).
As one can see, FDC shape over the length of the river in investigated GS is very similar that can be explained by the gradually varied hydrological-hydraulic regime of the river. More significant differences are identified within the area of especially high discharge occurrence. On the other hand, they are not of great importance for the HK energy output.

**Velocity histograms**

In the scientific literature consistent patterns of river flow velocity have not been widely considered. It is clear that the main cause of the lack of this information is related to the temporal and spatial fluctuation of flow velocity. Histograms of flow velocity at GS were derived on the basis of multi annual daily flow duration curves and velocity - daily discharge rating curve (Fig. 3).

The above histograms exhibit the distribution of flow velocity, determined according to the data of daily discharge measurement from 1986 to 2010, during the average year. The goodness of fit of a probability distribution was tested by comparing the theoretical and sample values of the relative frequency function and cumulative frequency function (the later not shown there). It is obvious, distribution of flow velocity within a year does not correspond to the normal distribution whereas that of the velocity is best fitted by the extreme value (type I) and logarithmic normal distribution. The summarized flow velocity statistical data is provided in table 2.

**Table 2. Statistical data of flow velocity for the Neris river GS**

<table>
<thead>
<tr>
<th>GS</th>
<th>Sample</th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>Max</th>
<th>Min</th>
<th>Coef. Variation</th>
<th>Skewness</th>
<th>Probability Density Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Buivydziai</td>
<td>365</td>
<td>0.64</td>
<td>0.12</td>
<td>1.26</td>
<td>0.45</td>
<td>19.2</td>
<td>2.06</td>
<td>Extreme (Type I)</td>
</tr>
<tr>
<td>Vilnius</td>
<td>365</td>
<td>0.70</td>
<td>0.17</td>
<td>1.67</td>
<td>0.48</td>
<td>23.9</td>
<td>2.22</td>
<td>Extreme (Type I)</td>
</tr>
<tr>
<td>Jonava</td>
<td>365</td>
<td>0.77</td>
<td>0.17</td>
<td>1.69</td>
<td>0.54</td>
<td>22.3</td>
<td>2.16</td>
<td>Lognormal</td>
</tr>
</tbody>
</table>

Lalander et al. (2013), using the data of velocity in 5 Alaskan unregulated rivers to deploy HK turbines could not fit the proper velocity distribution for cross-section of the rivers due to the instability of velocity regime (sample of
GS data validation with the results of the hydraulic model HEC-RAS

Hydraulic and geometric characteristics of the Neris river flow were simulated using one-dimensional hydraulic model HEC-RAS (Punys et al., 2013). All river from the mouth to the border with Belarus was divided into 2380 cross-section profiles where the main hydraulic (mean velocity, Froude number, roughness, power of the flow) and geometric (width of the bed, mean depth, area of cross-section) characteristics were identified. It was tested how the modelled characteristics comply with the derived data of the three GS. Characteristics were compared, the flow rate being mean, bankfull, and low water. Modeled and derived stage magnitudes are most compatible while differences in mean velocities and cross section areas are slightly bigger. Due to existing uncertainties, it is impossible to reach higher compatibility.

When analyzing hydraulic and geometric parameters at GS, a crucial conclusion was drawn up that transposing these parameters over the length of the river based on the equations 3 to 5 is completely impossible. Consequently, these relationships are of little use for assessing the riverine hydrokinetic resource at a site of interest. This statement can be supported by the graph below, taken from the hydraulic model HEC-RAS results, illustrating an enormous variation of water surface width, flow cross sectional area and velocity.

As one can see the variance of hydraulic and geometric variables at cross sections is very large, only general trends with the weak relation ($R^2=0.53$ to 0.61) can be seen for water surface width and cross section area. The most significant is the velocity data, they are very scattered, and no trend can be detected with river discharge. From the following, it can be stressed that hydraulic modeling employing river bed DTM is only one key method for HK resource assessment and site selection for hydropower generation. Field measurements are a must for results validation.

Assessment of resources

Using formulae (1 and 2) the mean annual HK power and its density were calculated in GS according to the flow velocity histograms (table 3).

<table>
<thead>
<tr>
<th>Indices</th>
<th>Buivydziai</th>
<th>Vilnius</th>
<th>Jonava</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean annual discharge $Q_0$, m$^3$/s</td>
<td>66</td>
<td>99</td>
<td>167</td>
</tr>
<tr>
<td>Flow area $A$, m$^2$</td>
<td>130</td>
<td>130</td>
<td>200</td>
</tr>
<tr>
<td>Power density $D$, kW/m$^2$</td>
<td>0.16</td>
<td>0.21</td>
<td>0.27</td>
</tr>
<tr>
<td>Capacity $P$, kW</td>
<td>21.2</td>
<td>26.8</td>
<td>53.2</td>
</tr>
</tbody>
</table>

HK power density in wet (10 %), average (50 %) and low water (95 %) year was developed on the basis of GS daily discharge using the correlation between velocity and the discharge as well as formula 2. The year in terms of water abundance or scarcity was defined using the record of discharge of 50 years (1960-2010). The highest density of power was identified in spring period during the months of flooding while the lowest it is in the summer. In the wet
year, in spring period the value of D can be up to 1.2, whereas it is about 0.4 kW/m² in the dry year. Winter season is not appropriate for HK power generation.

It is difficult to compare the obtained results with other rivers due to limitations of the information. For example, in Alaska, the mean HK density of power ranges from 0.3–0.4 to 1.9–6.5 kW/m² (Johnson, Pride, 2010; Previsic et al., 2008).

Conclusions

The relationship defined by correlations of flow velocities, cross-section area, and discharge established for the Neris river GS is best reflected by a power function, is close and robust.

The shape of flow duration curve over the length of the river in different GS is similar and hydrologico-hydraulic regime of the river is uninterrupted. More significant differences were identified in the area of especially high discharge repetition. Nevertheless, they are not of importance for the energy output.

Distribution of the extreme value is well suited for the equation of empiric data except for the extreme velocities of flow.

Hydraulic modelling, using the digital model of the bed bathymetry is the main and the most precise method for the assessment of HK energy resources and selection of the most efficient location so that hydropower could be generated, whereas hydrometric measurements are crucial only for validation of the data.

The highest HK energy power density was defined in the months of spring during flooding, whereas it is lowest in the summertime. In the wet year, in the spring the value of D can reach 1.2, whereas in low water year remains only 0.4 kW/m². Winter period is not appropriate for HK energy output.

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References


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Influence of Vertical Crust Movements on Accuracy of Reference Geodetic Levelling Network

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Abstract

Theoretical research enabled to work out the methodology targeted to estimate the impact of the recent vertical ground movements on accuracy of reference geodetic levelling network. The methodology proposed makes it possible to plan repeated geodetic measurements of levelling networks to achieve required accuracy.

The methodology is presented allowing reduction of measured differences in altitudes taking into account trends in vertical ground movements in selected moment of time. By reducing the measurements the influence of systematic errors is decreased due to the impact of vertical movements of the Earth’s crust on to the errors of levelling.

Regressive models are derived by means of the general mathematical statistical analysis of repeated geodetic measurements and incorporation of geo-indexes. The models are applied in forecasting the velocities of vertical ground movements required for the evaluation of the impact of vertical movements of the Earth’s crust on the measured differences of altitudes and for performing reduction of measurements notifying the selected moment of time.

Explore to assess the impact of the vertical movement of the Earth’s crust for the levelling networks of Lithuania. The conclusion derived implies that in 10 years about 70% of the first-class levelling networks would not satisfy the accuracy requirements for maintenance. Accuracy requirements for the second class network in 10 year would not be satisfied by about 55%.

The sums of reduction corrections of altitude differences in separate observations, in terms of the Lithuanian first class levelling network when specifying the selecting moment of time, up to four times exceed the sums of normalized corrections.

Keywords: vertical movements of the Earth’s crust, horizontal gradients, errors occurred due to the impact of the vertical movements of the Earth’s crust, normal corrections, time moment, levelling line.

Introduction

The geodetic levelling network is established in Lithuania in order to provide a unanimous basis of the altitudes. The benchmarks are embedded in the ground and is subject to some vertical movements of different nature (ground water level fluctuations etc.), including tectonics. The surface processes are of cyclic nature, while geodynamic processes may lead to significant long-term or irreversible changes in altitudes. The latter are the subject of the present study.

Geodynamic processes are considered to be the continuous natural processes. The intensity and trend of the ground movements vary significantly in Lithuania. With time, because of the impact of the vertical movements, the errors in measured altitudes tend to increase. The more intense the vertical ground movements, the greater is their impact on accuracy of levelling network violating thus the requirements on accuracy of the geodetic network. When evaluating the change and intensity of the vertical movements of the Earth’s crust it is necessary both to judge their impact on the results of the levelling measurements in time and plan the repeated measurements of a network.

Measurements of a reference levelling network are repeated in one or several years. The levelling lines in which the measurements are made within different periods of time later are connected into the levelling network. In some cases the time span is several years and the results of the measurements are inevitably affected by geodynamic processes causing errors. Due to continuous geodynamic processes the altitudes change. In case measurements are carried out within the same levelling line but in different years the incorrect altitudes (or rather altitudes for different base levels) are derived. In order to avoid the impact of the vertical movements of the Earth’s crust on results of geodetic measurements it is necessary to reduce errors taking into account long-termed geodetic trends.

Methods

The recent vertical movements of the Earth’s crust could be considered as the physical phenomenon of the continuous nature in the territory. The area (plane) can be approximated by a set of points and the set of scalar quantities could be obtained. That part of space comprises the scalar field (Копыр Г., Копыр Т. 1970). At each point of the field the appropriate scalar quantity characterises a certain physical phenomenon taking place at that point at a certain moment of time, in our case they correspond to the vertical movements of the Earth’s crust. Assuming that the scalar quantity changes only in cases when there is a transition from one point of the field to the other point of the same field, then the scalar quantity is the space point in which the change takes place. Then the movements of the Earth’s crust could be described (Zakarevičius 1994):

\[ h = f(x, y, t), \]  

(1)

here \( h \) is the vertical movements of the Earth’s surface; \( x, y \) are rectangular coordinates; \( t \) is the time span between the repeated levelling campaigns.

Assuming that within the cycle of repeated levelling measurements the velocity and direction of the current vertical movements of the Earth’s crust do not change, when differentiating the formula (1) by scalar field variable \( t \), one gets the scalar field of the velocities of the vertical movements of the Earth’s crust, which is the function of the plane coordinates:
The map of the vertical movements of the Earth’s crust can be thus compiled. The function of the horizontal gradient modules of these movements is derived by differentiating the function of the scalar field (2) in reference to the plane coordinates x,y:

$$|\text{grad} V| = \sqrt{\left( \frac{\partial f(x,y)}{\partial x} \right)^2 + \left( \frac{\partial f(x,y)}{\partial y} \right)^2}.$$  

(3)

By applying formula (3) the calculated values of the horizontal gradient modules of the velocities of recent vertical movements of the Earth’s crust it is possible to present in a diagram and compile the map of gradients.

In case the analytical expression of the scalar field function (3) of the velocities of the vertical movements of the Earth’s surface is missing, but there is available only the field, presented in the form of a diagram (map of the velocities of the vertical movements of the Earth’s surface), or the digital values at the points, then the values (3) of the horizontal gradients of the velocities of the movements are possible to be calculated by making use of the methods of digital differentiating (Zakarevičius 1994; Уломов 2004). After the assumption made on the change of the vertical movements of the Earth’s crust between the isolines $V_i$ and $V_{i+1}$ together with the distance between them $D_{i,i+1}$ to be considered to have the linear character, the number value of the gradient is calculated by applying the formula (Уломов 2004):

$$|\text{grad} V| = \frac{(V_{i+1} - V_i)}{D_{i,i+1}}.$$  

(4)

In case both the values of the horizontal gradients of the vertical movements of the Earth’s crust and the time passed after the compiling of the levelling network are known then it is possible to calculate the impact of these movements on the change of the accuracy of the levelling network within the shift of time.

Therefore, if the levelling network is maintained during the number of years $t$, then the systematic errors of the measured differences of altitudes due to geodynamic impact, and 1 km of levelling section could reach the absolute values $m_\delta$

$$m_\delta = |\text{grad} V| \cdot t ,$$  

(5)

here $m_\delta$ is the error of the differences of altitudes because of the vertical movements of the Earth’s surface, $t$ is time expressed in years after the measurements were taken (Zakarevičius 1994).

In the sequence of time the vertical movements of the Earth’s crust influence the measured differences of altitudes according to the same regularities as systematic errors of the measuring. The summary mean square error of the altitude differences of the measured levelling section when evaluating the random errors of measurements and systematic errors of measurements are the following (Гайдаев 1969)

$$M = \sqrt{Lm_\delta^2 + L^2 m_\delta^2},$$  

(6)

here $L$ is the length of the levelling section in km; $m_\delta$ are the values of the random and systematic errors of the measurements for one kilometre.

The systematic errors always have to be lower than the random errors of measurements (Skeivalas 2001), namely.

$$m_\delta = km_\Delta ,$$  

(7)

here $k$ is the coefficient which depends on the specification specifying what part of the random error could comprise the maximum allowable systematic error value for one kilometre of levelling section. In the theory of measurements it is accustomed to apply $k=(1/3 \sim 1/5)$ within the boundaries (Vekteris et al. 2000). Then the systematic errors could be eliminated.

From (6), (7) we derive

$$M = \sqrt{Lm_\Delta^2 + k^2 L^2 m_\delta^2}.$$  

(8)

Under the assumption that for $L$ kilometres of length of levelling section, the value $q$ is the ratio of the summary error to its systematic part of the component, then from the formula (8) it is possible to write the following:

$$\frac{(Lm_\Delta^2 + k^2 L^2 m_\delta^2)}{k^2 L^2 m_\delta^2} = q^2.$$  

(9)
The actual value of the coefficient $k$ on to the levelling section after evaluating the horizontal gradients of the velocities of the current vertical movements of the Earth’s crust within the number of $t$ years passed since the time of levelling would be

$$k = \frac{\text{grad}V \cdot t}{m_A}. \quad (10)$$

Taking into consideration (5), it is possible to write

$$k = \frac{m_\delta}{m_A}. \quad (11)$$

It is presumed (Busics 1999; Csepregi 1999; Ellmann et al. 1999; Kääriäinen 1999; Kasser 1999; Lilje, Eriksson 1999; Mäkinen, Saaranen 1999; Seto et al. 1999; Villadsen 1999a, 1999b; Wehmann 1999) in precise levelling that there are about 10% of the random errors, namely the coefficient is equal $k \approx 0.1$.

It is accepted in geodesy studies that when in the functions of the measured values the impact of one of the two error sources is specified by a mean square error not exceeding 1/3 of the mean square error which is called as the summary accuracy, then this source of errors could be ignored when evaluating the accuracy of measurements (Гайдаев 1969). Following the specification the value of the coefficient (9) is $q \approx 3$, but the measurements of levelling do not correspond the requirements of accuracy after one year period (5, 7).

$$t \geq \frac{M}{3|\text{grad}V|}. \quad (12)$$

In the precise levelling carried out in the territories the value of the random mean square errors for one kilometre of the proceeding are normally equal to $m_\varepsilon = 0.5 \text{mm}$ (Busics 1999; Csepregi 1999; Ellmann 1999; GKTR 2.12.01.:2001 Lithuanian… 2001; Kääriäinen 1999; Kasser 1999; Lilje, Eriksson 1999; Mäkinen, Menzel 1999; Saaranen 1999; Seto et al. 1999; Villadsen 1999a, 1999b; Wehmann 1999).

When applying formulae 5, 6, 7, 9 it is possible to calculate what errors of the measured altitude differences due to the impact of the vertical movements of the Earth’s crust would be after a certain period of time and taking into account the accuracy requirements applied for the relative class of levelling it is possible to determine during the research what lines of levelling as well how many percent of the vertical network located in the territory of Lithuania would not satisfy the requirements of accuracy after a certain period of time.

To compile the levelling network it takes more than one year to carry out the works. The measurements on the levelling lines are usually executed not during the same years. By joining these lines into the levelling network we obtain the results of the measurements made under the impact of the geodynamic processes. To avoid the influence it is required to apply corresponding errors, the results of measurements have to be reduced in reference to the selected time period.

Therefore, to calculate the errors one has to know the velocities and the gradients of velocities of the vertical movements of the Earth’s crust within the territory where the levelling lines are laid as well as the results of the latest levelling, because within the sequence of time the character of the vertical movements of the Earth’s crust tend to alter as it has been proved by the investigations carried as well as both the velocity of the movements and the direction tend to change (Bunichiro 2013; Celik 2010; Koler et al. 2011; Kontny, Bogusz 2012; Marin-Lechado et al. 2010; Spampinato et al. 2013; Silabriedis 2010). The results of the recent measurements are influenced by the current tectonic processes that are why the data obtained are relevant to determine the characteristics of these processes which in their turn are used to calculate the errors of these measurements by employing reverse correlation.

To eliminate abnormalities caused by random reasons as well to determine the general regularities in investigating the measured vertical movements of the Earth’s crust it is possible here to introduce regressive analysis. In case the measured vertical movements of the Earth’s crust are investigated in the separate lines of levelling the most appropriate is the linear model where the dependant variable is considered as velocity $V$ of the vertical movements, the independent variables are considered as geo- indexes $X_m$ (Spiegel, Stephens 2011; Дрейпер, Смит 1986):

$$V = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_m X_m + \varepsilon, \quad (13)$$
or the polynomial regressive model in which the dependant variable is the velocity of the vertical movements specified by this model and the independent variable is $S$ (the distance of the geodetic mark from the initial point of the levelling line (Zakarevičius, Stanionis 2012))

$$V = \beta_0 + \beta_1 S_1 + \beta_2 S_1^2 + \beta_3 S_1^3 + \ldots + \beta_m S_1^m. \quad (14)$$

Therefore, we have polynomial regressive models (14) of the velocities of the vertical movements or the models of the velocity gradients

$$\text{grad}(v) = F_{\text{grad}}(S) = f(S), \quad (15)$$
for the differences of altitudes $h_{ij}$ of the correction, measured between the points $i$ and $j$ to carry out the reduction taking into account the selected time moment when the distances from the initial point of the line $S_i$ and $S_j$ are calculated according to the formulae (Zakarevičius 2007):

$$\delta h_{ij} = (T_0 - T) \left[ F(S_j) - F(S_i) \right]$$

(16)

where $T_0$ is the time moment into which are reduced the results of the measurements; $T$ is the time moment of levelling; $S_i$, $S_j$ are the distances from the beginning of the levelling line to the geodetic marks $i$, $j$.

In order to evaluate the influence of the recent vertical movements of the Earth’s crust on to the levelling networks it is necessary to determine the field anisotropic characteristics of the vertical movements and their change in the territory. To fulfil that it is required to compile the map of the horizontal gradients of the vertical movements of the Earth’s crust. Such a map of the horizontal gradients has been compiled in the research process and the map of the velocities of the recent vertical movements of the Earth’s crust for the territory of Lithuania was compiled by Zakarevičius, Šliaupa and Anikėnienė (Zakarevičius et al. 2008; Zakarevičius et al. 2009) that served as a base in the present study.

To derive the values of the gradients the digital differentiating of the map was performed. The territory was split into polygons 15×15 km large. At nodes we determined velocities of recent vertical movements. The translation weight average was applied to carry out the generalization.

**Results of the investigation**

With the help of these data available we calculated the horizontal gradient modules of the velocities of vertical movements of the Earth’s crust and compiled the map of the horizontal gradients (fig.1.).

Figure 1. Map of horizontal gradient modules of the current vertical movements of the Earth’s crust (gradient values are ((mm/m.)/km)

Following Lithuanian regulations (GKTR 2.12.01.:2001 Lietuvos valstybinis… 2001) the error of the levelling of the first-class network should not exceed 0.5 mm/km. For the second-class network it is less than 0.7 mm/km.

As it has already been mentioned, geodesy prescribes the provision that when evaluating the accuracy of the measurements it is possible to ignore it in case the impact on the functions of the measured values from one of the two sources does not exceed 1/3 of the mean square error specifying the summary accuracy. However, if the influence of this source of errors is higher, it is not allowed to be disregarded (in this case $q \approx 3$). Having in mind this provision and with reference to the accuracy requirements available for the networks of levelling it is derived that the first class levellings do not satisfy accuracy requirements when the part of the mean square error appearing due to the influence of the vertical movements of the Earth’s crust are higher than 0.17 mm/km, the second class levellings are 0.23 mm/km.

With the numerical expression of the horizontal gradient modulus available, it is possible to calculate what mean square errors of the altitude differences could be for one kilometre of levelling proceedings after 10, 15 and 20 years of maintenance of the network of levelling. If the values of the horizontal gradient modulus of the vertical movements of the Earth’s crust are multiplied by a certain period of time and taking into account the approved value (here $q=3$) of the coefficient $q$ (formula 9), there are derived the values of the mean square errors of the altitude differences after a certain period in the territory under investigation.

During the research it has been found what quantities would be attained by the values of the mean square errors of the altitude differences in the territory under the investigation after a certain period of time and afterwards in accordance with the location of the levelling line laid it has been defined after what exact period of time the results of the measurements made on this line contravene the requirements of accuracy attached to them. The results of the research are presented in table 1. The sign “+” marks the lines of levelling after an appropriate period of time which
correspond the accuracy of the levelling network, the sign “—” indicates the lines of levelling after the appropriate period of time which do not correspond the accuracy requirements of the network of levelling.

Table 1. Meeting the requirements of accuracy for networks of levelling under the impact of the vertical movements of the Earth’s crust

<table>
<thead>
<tr>
<th>Levelling line</th>
<th>Appropriate accuracy requirements after years</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>I class</td>
</tr>
<tr>
<td>Šiauliai–Kužniai–Mažeikiai–Lūšė</td>
<td>—</td>
</tr>
<tr>
<td>Šiauliai–Tauragė–Mikytai</td>
<td>+</td>
</tr>
<tr>
<td>Mikytai–Šilutė–Klaipėda–Palanga–Būtingė</td>
<td>+</td>
</tr>
<tr>
<td>Jonava–Kaunas–Kazlų Rūda–Kybartai</td>
<td>—</td>
</tr>
<tr>
<td>Vilnius–Jonava</td>
<td>—</td>
</tr>
<tr>
<td>Jonava–Zarasai–Turmantas</td>
<td>—</td>
</tr>
<tr>
<td>Turmantas–Vilnius</td>
<td>—</td>
</tr>
<tr>
<td>Jonava–Šiauliai–Joniškis</td>
<td>+</td>
</tr>
<tr>
<td>Kazlų Rūda–Šeštokai–Lazdijai–Poland’s border</td>
<td>—</td>
</tr>
</tbody>
</table>

As the findings of the research indicate (table 1), 55% of the I class an II class will not meet the levelling accuracy requirements already after 10 years, 67% of the levelling networks located in the territory of Lithuania will not meet I class requirements.

After 20 years not only class I but also class II fail to meet the requirements for the accuracy of levelling and about 67% of the levelling networks, and class I requirements fail to meet 100% of the networks, after 30 years all the analysed lines of levelling fail to meet the requirements for the accuracy of levelling (100%).

Taking into account the results obtained from the research (Table 1, Fig. 1), it is obvious that about 70% of the levelling networks due to the impact of the vertical movements of the Earth’s crust the accuracy requirements after ten years will not meet the standards. That is why we presume the following. In order to preserve the required accuracy of the vertical networks the repeated measurements have to be carried out for the first and second classes levelling networks in the territory of Lithuania every 15-20 years.

The impact of the vertical movements of the Earth’s crust has to be evaluated when processing the results of the levelling networks measurements. The results of the measurements have to be reduced taking into account the selected time period, calculating the errors occurred due to the impact of the vertical movements of the Earth’s crust on the data of the measurements carried out at different time.

The polygon Jonava–Zarasai–Turmantas–Vilnius–Jonava was selected for trial analysis. It consisted of the levelling lines Jonava–Zarasai–Turmantas, Vilnius–Jonava and Turmantas–Vilnius. These lines were measured within the accuracy of 0.34–0.69 mm/km, the measurements were dated in 1985–2006. In that part of the country there were determined rather great velocities of the vertical movements of the Earth’s crust (Zakarevičius et al. 2008; Zakarevičius et al. 2009) as well as their horizontal gradients (fig.1).


Judging from results of the measurements carried on the lines of the analysed polygon for the levelling process there were calculated the velocities of the vertical movements of the Earth’s crust and the values approximated by their polynomial regressive models (table 2).

Table 2. Polynomial regressive models of the velocities of the vertical movements of the Earth’s crust

<table>
<thead>
<tr>
<th>Regressive models</th>
<th>( R^2 )</th>
<th>F</th>
<th>( F_{q^*} ) (( q = 0.01 ))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jonava–Zarasai–Turmantas</td>
<td>96.4</td>
<td>284.4</td>
<td>5.8</td>
</tr>
<tr>
<td>( v = -0.735 + 0.032 \cdot S - 0.4 \cdot 10^{-7} \cdot S^2 )</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Turmantas–Vilnius</td>
<td>95.8</td>
<td>274.7</td>
<td>5.6</td>
</tr>
<tr>
<td>( v = 3.987 - 0.061 \cdot S + 0.1 \cdot 10^{-7} \cdot S^2 )</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vilnius–Jonava</td>
<td>81.0</td>
<td>23.5</td>
<td>7.2</td>
</tr>
<tr>
<td>( v = 0.015 - 0.005 \cdot S - 0.2 \cdot 10^{-7} \cdot S^2 )</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

From the results presented in table 2 it is stated that on the applied levelling lines the measured velocities of the vertical movements of the Earth’s crust are rather adequately reflected by \( p \geq 0.99 \) the polynomial models of the second and third row. When the probability is \( p = 1-q \geq 0.99 \) and on all the lines \( F > F_{q^*} \), it is assumed that the values approximated by these regressive models are adequate to the values of the vertical movements of the Earth’s surface.

The greatest part of the levelling lines for the polygon Jonava–Zarasai–Turmantas–Vilnius–Jonava was measured in 2005, that is why the differences of the altitudes measured, during the last carried out measurements, are reduced taking into account year 2005. In this case a great number of the measured differences of the altitudes do not require to be reduced into the selected time period that is why during the experiment there was selected the other moment of time within the assumption that in certain cases the polygon might consist of the levelling lines in which there is a longer period of time among the last measurements carried out at that time or that polygon could be joined to the whole
levelling network of the country, where the lines were measured in 1998 – 2006. In the second case for the reduction of the altitude differences there has been chosen the year 2000 taking into account the selected time moment.

Together with the sequence of the research the numerical values of the calculated errors to the measured altitude differences due to the impact of the current vertical movements of the Earth’s crust at the levelling polygon of Jonava–Zarasai–Turmantas–Vilnius–Jonava vary within the boundaries of 0.73 – -0.53 mm (year 2000) and within the boundaries of 0.12 – -0.11 mm (year 2005). The findings indicate that the values of the corrections made depend on the period, differentiating the selected time moment into which we will reduce the measured differences of altitudes from the years in which the measurements have been made as well as on the velocities of the Earth’s deformations, their changes, and the horizontal gradients of the vertical movements serve for the best manifestation of that.

There are calculated the normal altitudes of the geodetic station of the levelling polygon, the measured non reduced altitude differences are taken for calculations with respect to the selected time moment and the reduced altitude differences with respect to years of 2000, 2005. The initial station is the 217th geodetic station, the normal altitude of which is $H_{217} = 68.697$ m (Lietuvos valstybinio... 2006).

The allowable non-correlation is calculated according to the formula:

$$f_{h_{nu}} = \pm 1.5 \sqrt{L}.$$  

(17)

The perimeter of the polygon Jonava–Turmantas–Vilnius is 451.05km that is why the allowable non-correlation will be $\pm 31.86$mm. During the process of the research the attained non-correlations in the polygon, when in calculations there have been applied the non-reduced altitude differences, with the reference to the selected time moment, as well as by reducing them with respect to years 2000, 2005 and thus table 3 presents them.

Table 3. Non-correlations at the levelling polygon of Jonava–Turmantas–Vilnius–Jonava

<table>
<thead>
<tr>
<th>Altitude differences</th>
<th>Non reduced with respect to the selected time moment</th>
<th>Reduced into:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>2000 year</td>
</tr>
<tr>
<td>Non-correlations, mm</td>
<td>+4.39</td>
<td>+5.76</td>
</tr>
</tbody>
</table>

In order to investigate the impact of the reduction into the selected time moment of the measured altitude differences on to the altitudes of the geodetic marks, the polygon is levelled and there are calculated the altitudes of the geodetic marks by means of the measured and reduced altitude differences. The differences between the altitudes of the geodetic marks are determined which have been calculated by applying non-reduced differences of altitudes and considering years of 2000, 2005 with reduced differences of altitudes. The diagram presents these differences for the levelling line Turmantas – Vilnius in figure 2.

![Figure 2. The difference presented between the measured and correspondingly between the reduced with respect to 2000 (I difference) and with respect to 2005 (II difference) on the levelling line of normal altitudes for Turmantas–Vilnius](image)

The greatest differences taken between the levelled measured and levelled reduced with respect to the selected time moment at the polygon of normal altitudes of Jonava–Zarasai–Turmantas–Vilnius–Jonava exceed to 23.5 mm (for 2000) and 5.1 mm (for 2005).

Conclusions

1. The methodology was elaborated to evaluate the impact of the recent vertical movements of the Earth’s crust on geodetic levelling network and change in network accuracy.

2. The methodology is proposed to reduce errors in levelling measurements to avoid the impact of recent vertical movements of the Earth’s crust on the measured differences in altitudes.

3. In 10 years the 1st class levelling network due to impact of vertical movements of the Earth’s crust have a tendency to cause a failure in accuracy for about 67%, whereas in 20 years the failure reach 100%. It is recommended to perform the repeated measurements of the levelling networks as often as 15 – 20 years.

4. The corrections applied in reducing the measured differences in altitudes in the polygon Jonava – Zarasai – Turmantas – Vilnius – Jonava amount up to 0.73 mm.
Asta ANIKĖNIENĖ, geodynamic processes, investigations of deformations.

Rūta PUZIENĖ, Rural Development 2013                                                                                                                                                 ISSN  2345-0916


Investigations of Groundwater Quality in Environment of Karst Sinkholes

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Abstract

The paper overviews the research material related to occurrence of sinkholes and change of their water quality in the conditions of increasingly natural environment and minimal anthropogenic impact. Sinkholes create favourable conditions for interaction of surface and groundwater. Identification of possible sources of sinkholes pollution is very important in solution of groundwater safety problems. Water quality investigations are carried out in 2 sinkholes and 2 groundwater wells. Sinkhole water quality may worsen due to accumulation of organic materials (increasing peat content). Water of peat-filled sinkholes has bigger amounts of N-NO$_3$ and SO$_4$ than groundwater in well. A more significant difference of water quality was found between well water in mineral soil and sinkhole.

Key words: karst zone, sinkhole, groundwater, water quality.

Introduction

The karst phenomena occurs in different countries. Central America constitutes carbonate karst landscape with an area totalling about 23% of its total land (Kueny and Day, 2002). Slovenian karst areas extend over 43% of the country, where karst groundwater contributes up to 50% of the total drinking water supply (Kovačič and Ravbar, 2005). Over 80% of Serbian population and industry use groundwater for water supply. The main aquifer systems are formed in alluvial deposits and highly karstified carbonate rocks (Stevanović et al, 2007). The karst groundwater use in the North and South China (Lu, 2007).

The subsurface of all three Baltic Republics of Estonia, Latvia and Lithuania with a total area of 175,000 km$^2$, is composed of karst sediments of various age and type. Karst in the North Lithuania is matured not only at the land surface but also in the subsurface. Surface karst forms are represented by sinkholes, karst shafts, land subsidences, lakes, dolines, etc. Subsurface forms are the enlarged dissolution voids, cavities and caves. More than 8500 sinkholes, different in size and shape, are counted in the region of active gypsum karst covering the area of 400 km$^2$ (Paukštys, 1996; Narbutas et al., 2001).

Under normal conditions the concentration of Ca, SO$_4$, Mg, HCO$_3$ ions in the Lithuanian surface waters rarely exceed the maximum concentration limits adopted in Lithuania. However, in the karst landscape these concentrations are often higher due to dissolution of gypsum and dolomite (Satkūnas et al., 2006).

The rate of chemical denudation of soluble rocks is one of the main factors determining the intensity of karst process. Due to rapid water circulation between surface and underground water, gypsum rocks dissolve and are carried out to the Lielupe River. The highest intensity of gypsum denudation is during the spring flood, the lowest in the dry period. In comparison with 2009, it increased from 156 to 167 m$^3$ km$^{-2}$. This denudation intensity value is by 9% lower than the average value for 1994-2010 yet even by 44% exceeds the value for 1963-1979 (Taminskas, 1999; Taminskas and Mikulėnas, 2010; Taminskas et al, 2011).

The unique ecological structure with a variety of biological processes is formed by specific conditions in water bodies. Karst lake bottom sediment is the ecological zone, where specific econiches are formed by organisms decomposing organic substances till the final products – CO$_2$ and H$_2$S (Paškauskas et al., 1998).

Some new (for Lithuania) species of zooplankton were found in karst region water basins - Keratella valga Ehrenberg, K. valga heterospina Klausener, K. testudo Ehrenberg, Notholca labis Gosse, Notomata aurita Muller, Bosmina kessleri Uljanin. According to amount and species of planktonic algae in the lakes, sinkholes and Tatula river are an eutrophicated water body (Kasperovičienė et al., 1998).

In an ecologically susceptible karst zone, a regular formation of sinkholes is a hazard for the safety of people and buildings and creates favorable conditions for the migration of contaminants into the groundwater. Polluted drinking groundwater is dangerous for people’s health. The salt-saturated water becomes more aggressive and intensifies karst process of the rocks lying below.

The main human activities influencing karst development are groundwater extraction and agriculture (Paukštys, 1996). The foreign researches (Dell Rose et al., 2004) maintain that karst formation may be either natural or caused by man’s activities.

The naturalness of environment not always ensures the proper water quality. Water quality can decline due to unused arable land, which is not taken care of, the meadow overgrown with scrub and trees or fallow and other natural changes in the environment.

The trees and the shrubs in the channels at the beginning of vegetation had an impact on water quality (nitrate nitrogen concentration decreases) (Lamsodis, 2001). The microorganism increased in the surface of virgin soil. However, nutrients leached more intensively, especially nitrogen (Žėkaitė et al., 2007).

In the karst region, where the hydraulic link between the surface and groundwater is very good, even small sources of pollution (pollutants from precipitation and surface runoff, remains of decomposition of organic materials) may entail substantial changes of ground water quality (Taminskas, 2002).

In order to protect groundwater quality in karst region, it is necessary to obtain comprehensive information about the natural processes in this region.
The aim of the paper is to ascertain the peculiarities of change groundwater water quality of sinkholes vicinity.

Object and research methods

Geological and hydrological setting of the Lithuanian karst region

The karst processes highly active in North Lithuania (mainly in Biržai and Pasvalys administrative districts) are related to Upper Devonian gypsum and dolomites that occur beneath the Quaternary cover. The cover of karstified rocks consists mainly of Quaternary deposits (loam and sandy loam, sand, gravelly sand, gravel clay, silt) (Марцинкявичюс и Буцявичюте, 1986; Narbutas et al., 2001; Dėnas and Račkauskas, 2005).

The thickness of the cover of karstified rocks in the karst area varies from parts of the first meter up to 70m and has a common tendency to increase southwards and especially westwards (Марцинкявичюс и Буцявичюте, 1986). Sinkholes are located in the areas with the cover thickness less than 25 meters. In the areas where the cover thickness is up to 5 m new sinkholes are forming intensively.

The North Lithuania karst region is located in the eastern part of the Baltic artesian basin. The active water change zone is up to 270 m thick and includes aquifers in the Quaternary and in the Įstras –Tatula, Kupiskis-Suosa, Sventoji-Upninkai formations of the Upper Devonian. This series of aquifers is underlain by the 60-100 m thick regional aquitard of the Narva Formation. Variations in level and chemical composition of groundwater are determined by the rate of infiltration of precipitation. Ground collapse usually affects the Quaternary cover and permits ready recharge of surface water into the Upper Devonian aquifers. Areas with such intensive water circulation in open gypsum systems are referred to as the intensive karst zone (Juodkazis, 1992; Paukštys, 1996; Satkūnas et al., 2006). Water of the aeration zone mostly infiltrates through vertical fissures until it reaches either horizontal channels or impermeable soil layer. A large amount of rainwater is collected in the bottom of the sinkholes, which are open holes or filled with permeable deposits (Narbutas et al. 2001).

Most of the sinkholes of the karst region are dry. They collect and temporarily retain atmospheric or groundwater only during spring floods. The newly occurring sinkhole in the course of time becomes shallow as a result of sedimentation processes and transforms into small bogs. As a result of a very good hydraulic link between the surface and ground water, part of sediments is eliminated with the ground runoff (Taminskas, 1999).

Location of studied site

The studies of water quality in sinkholes and groundwater wells were carried out in moraine sandy loam and peat soils of active karst zone in 2008-2012. The studies site is situated at the headwater of stream G-1 tributary of the Apaščia, in Biržai district (Fig.).

Figure. Scheme of study site
The sinkhole 1 was old age and peat – filled, covered with marsh vegetation, it was usually dry in the summer. The sinkhole area is 0.105 ha. Sinkhole was surrounded by meadows, at 25 m distance from the stream G-1.

The sinkhole 2 (few merged sinkholes) was old and peat – filled, overgrown with trees and shrubs, it is dry in the summer. The trees and shrubs covered area was 0.572 ha.

In the sinkholes wells (h=2-3 m) were installed, water quality observe while surface water were absent in sinkhole.

The quality of groundwater investigated in well 1 (h=5.7 m) was installed 21 m from a sinkhole 1 in peat soil and in well 2 (h=8.8 m) was installed 23 m from a sinkhole 2 in mineral soil.

Analysis of water and slopes soil samples was carried out at the Chemical Analysis Laboratory of Water Management Institute of ASU. Chemical analysis included the following methods: nitrate-nitrogen (N-NO\textsubscript{3}) – gravimetric, pH\textsubscript{KCl} (in soil samples) – potentiometric with glass electrode. Acidity – alkalinity index pH was from (5.18) to neutral reaction (7.73) in slope soil of investigated sinkholes (Table 1). The lowest value of pH\textsubscript{KCl} was found in the slope soil of sinkhole 2 within peat filled and overgrown with trees and shrubs. The highest amount of sulphates in slope soil was found in the sinkhole 2.

<table>
<thead>
<tr>
<th>Study place</th>
<th>N-NO\textsubscript{3}</th>
<th>SO\textsubscript{4}</th>
<th>Mean</th>
<th>Min</th>
<th>Max</th>
<th>St.dev</th>
<th>Mean</th>
<th>Min</th>
<th>Max</th>
<th>St.dev</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sinkhole 1</td>
<td>0.10</td>
<td>0.07</td>
<td>0.26</td>
<td></td>
<td></td>
<td></td>
<td>15.08</td>
<td>2.7</td>
<td>50</td>
<td>13.8</td>
</tr>
<tr>
<td>Well 1</td>
<td>0.06</td>
<td>0.62</td>
<td>0.14</td>
<td></td>
<td></td>
<td></td>
<td>12.2</td>
<td>1.9</td>
<td>45</td>
<td>11.3</td>
</tr>
<tr>
<td>Student’s test (t\textsubscript{a})</td>
<td>0.67</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.78</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sinkhole 2</td>
<td>10.9</td>
<td>32.2</td>
<td>10.9</td>
<td></td>
<td></td>
<td></td>
<td>89.6</td>
<td>12.0</td>
<td>172.0</td>
<td>46.8</td>
</tr>
<tr>
<td>Well 2</td>
<td>3.0</td>
<td>23.1</td>
<td>5.7</td>
<td></td>
<td></td>
<td></td>
<td>14.9</td>
<td>3.1</td>
<td>67.9</td>
<td>16.4</td>
</tr>
<tr>
<td>Student’s test (t\textsubscript{a})</td>
<td>3.04</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>7.21</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The difference is significant on condition that t\textsubscript{a}>t\textsubscript{0.05}=1.68

In sinkholes higher nitrate nitrogen concentrations (0.01-32.2 mg L\textsuperscript{-1}) were in the cold period than in the vegetation period (0.009-5.8 mg L\textsuperscript{-1}). During the summer time, when the photosynthesis intensifies in surface waters, the nitrate concentration reduces due to the fact that it is assimilated by aquatic organisms (Diliūnas and Kaminskas, 2003). Particularly high concentrations of NO\textsubscript{3}-N (average cold period 32.2 mg L\textsuperscript{-1}) were found in the sinkhole 2 covered with trees and shrubs in the spring. At this time, the water was usually upper to the ground. One of the reasons for determining the amount of nitrate nitrogen can be mineralization of tree leaves and shrubs and compound access with leaf. Depositions of nitrogen (oxidized and reduced) were increased under canopy because of wash – off dry deposition from foliage and foliar leaching. But the load of nitrogen under canopy during the vegetation period was...
smaller because of canopy uptake. The load of nitrogen under the canopy was reduced 2-3 times, the accumulation of nitrogen dominated (Juknyšs et al., 2002).

SO\textsubscript{4} concentration (up to 1175 mg L\textsuperscript{-1}) and Ca (up to 540 mg L\textsuperscript{-1}) dominated in the lake water, when the lake bottom connected with gypsum layers (Taminskas, 1997). It can be assumed that investigated sinkholes are mainly fed with rain water and water quality determines nutrient amount in the soil. The higher SO\textsubscript{4} concentrations were in sinkholes (2.7–172 mg L\textsuperscript{-1}) than groundwater wells (1.9-67.9 mg L\textsuperscript{-1}). The more humus and total nitrogen are in soil, the more sulphur is there. Sulphur compounds oxidized to sulphates in the aerobic condition. Sulphur is reduced to hydrogen sulphide in anaerobic condition. The low (0.01-0.8%) sulphur is in the mineral soil and more (1%) - in the peat soil (Adomaitis, 1998).

The highest concentrations of sulphate (12.0 to 172.0 mg L\textsuperscript{-1}) in the sinkhole 2 covered with trees and shrubs may be related to the tree canopy uptake and the sulfate amount (up to 216.2 kg m\textsuperscript{-2}) in peat soil. A particularly great part of sediments is composed of products of trees growing on the shores of lakes which directly get into the karst lakes. The tree products represent the main source of organic material and nutrients getting into the karst lakes (Taminskas, 1999). The water in the peat soil has more organic matter (Toth, 1999). In the sinkholes densely covered with trees, where the surface layer of water is in the shade, there is hardly any direct sunlight; therefore, the surface temperature is lower. This kind of isolation affects microorganisms (Žvikas et al., 2002).

The NO\textsubscript{3}-N and SO\textsubscript{4} concentration mainly fluctuate in well installed in mineral soil than in well installed in peat soil. This can be related with peat reduction environments.

Soils contained groundwater of different kinds of mineralization and is explained by different lithology of mother rocks and land use (Chelmicki and Siwek, 2001; Arustienė and Papievis, 2003). A more significant difference of water quality was found between well water in mineral soil and sinkhole.

**Conclusions**

Sinkholes create favourable conditions for interaction of surface and groundwater. Identification of possible sources of sinkholes pollution is very important in solution of groundwater safety problems.

Sinkhole water quality may worsen due to accumulation of organic materials (increasing peat content).

In most cases, N-NO\textsubscript{3} (0-0.97 mg L\textsuperscript{-1}) concentrations in water of sinkholes were similar to this concentration in precipitation (0.429 mg L\textsuperscript{-1}).

Water quality in peat-filled sinkholes and well is different. Water of peat-filled sinkholes has higher amounts of N-NO\textsubscript{3} (0-32.2 mg L\textsuperscript{-1}) and SO\textsubscript{4} (2.7-172.0 mg L\textsuperscript{-1}) than water in well.

A more significant difference of water quality was found between well water in mineral soil and sinkhole.

**References**


Aurelija RUDZIANSKAITĖ, dr., senior researcher of the Institute of Water Resource Engineering, Faculty of Water and land Management of Aleksandras Stulginskis University. Address: Parko 6, Vilainiai LT–58102, Kedainiai district, Lithuania. E-mail: Aurelija.Rudzianskaite@asu.lt. Research interests – environmental engineering, relations between the regime and pollution of surface and subsurface water.
Influence of Calcareous Liming Materials on Soil Acidity and Aluminium Mobility

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Abstract

Soil acidification is one of the major factors of soil degradation as it disturbs the functioning of soil ecosystems, increases toxic mobile aluminium, results in reduced soil productivity. It depends on the environmental conditions as well as soil genesis. For the Western Lithuania the genetic properties of soils (depth to the carbonates is 1.5-3 m) and soil leaching regime due to rainfall surplus is common resulting in leaching of the bases cations (Ca$^{2+}$, Mg$^{2+}$) and natural soil acidification. Therefore soils in that region are very sensitive to the acidification and requires for the periodic liming. Moreover the big intervals between liming procedures increases soil acidity even more. In the period of 1997 when liming was performed the last time to 2007 years the area of acid soils in Western Lithuania increased by 8.5%. In 2011 year there were 36.5% of acid soils ($p_{H_{KCl}}$<5.5) in that region. Therefore the need of liming of soils in Western Lithuania is of great importance. The question is just what liming materials are more effective and what recommendations of soil acidity management should be.

In order to investigate effectiveness of calcerous liming materials two experimental plots of Albeluvisols of different acidity (Eutric $p_{H_{KCl}}$ 4.27 and Dystric 5.82) had been instaled, each plot was divided into 5 subplots, and each subplot in area of 50 m$^2$ was limed with different liming materials of local origin (chalk, „agralkalkės“ (limestone and lime powder), crushed dolomite „Dirvitas“, and “kalktrąšė” (pel-lime, pelleted liming material). Experiment was performed randomly in four replicates and also control subplots without any liming were instaled in each replicate of the experimental plot. Soil $p_{H_{KCl}}$ was monitored for 18 months and liming efficiency of materials used on soil potential acidity and Al mobility was evaluated.

It was determined, that efficiency of liming materials depends not only on amount of pure CaCO$_3$ but also on their origin, chemical composition, reactivity, and granulometric composition as well as on soil acidity. The quickest effect occured of chalk (powdered material), but it was limited as after 12 month trend of soil acidity increase was determined in Dystric while after 18 months in Eutric Albeluvisol. In spite the bigger ag-lime reactivity and amendments of active CaO+MgO the liming effect was less but more stable than that of the chalk: in the Eutric Albeluvisol the liming effect appeared after 6 months while no effect on agriculte of soil pH$_{KCl}$ was less and statistically significant ($p$=0.05) just on the Eutric Albeluvisol after 18 months while no effect on Dystric Albeluvisol. Pel-lime during 18 month had no effect.

Key words: soil acidification, Albeluvisol, liming, chalk, ag-lime“, crushed dolomite, pel-lime.

Introduction

Purpose of investigation. Because of the rapid acidification of soils after last liming in Western Lithuania in 1997 due to soil properties (origin of the parent material, depth to the carbonates (2.0-3.0 m), low pH, low amounts of the organic matter and clay particles), climatic conditions (rainfall surplus and distribution during the year, as average annual amount (>800 mm) is more than in other zones of the Lithuania (600-700 mm) and 40% of rainfall is at the cool season from October to December when the fallow without crop cover is dominant), land reclamation, fertilizing and liming, and other agricultural activities what increase the need for periodic (supportive) liming, recently is of great importance (Veitenė, 2004; Koncius, 2008; Marcinkonis and Tripolskaja, 2008; Mažvila et al., 2008; Eidukeviciene et al., 2010). Soil liming improves the soil structure, regimes of the soil moisture, temperature and air ensuring the soil ecosystem functioning as well as optimizing availability of nutrients and mobility of pollutants, firstly toxic mobile aluminium as well as soil productivity (Čiuberkienė and Ežerinskas, 2000; Stenberg et al., 2000; Barabasz et al., 2002; Tang et al. 2003; Soon and Arshad, 2005; Lapinskas and Paulokaiči-Motuzienė, 2006; Manna et al., 2007; Bolan et al., 2008; Caires et al., 2008; Lalande et al., 2009; Mijangos et al., 2010; Clivot et al., 2012, Krstic et al., 2012).

The aim of the research was to investigate the effectiveness of calcerous liming materials of different granulometric and chemical composition on soil acidity and aluminium (Al) mobility in order to predict recommendations of the liming.

Object of the research. Two field experimental plots of Albeluvisols in the western Lithuania had been instaled:

1) Eutric Albeluvisol (ABe), sandy loam on light loam, acid (pH$_{KCl}$ 4.27±0.08), in the Girėnai, Rietavas distr. (55°37′; 21°59′);
2) Dystric Albeluvisol (ABd), sandy loam on light loam, acidulous (pH$_{KCl}$ 5.82±0.09), in the Pajūralis, Šilalė distr. (55°26′; 22°01′).

Meteorological conditions. In 2011-2012 years temperature varied ±2°C from average perennial. In 2011 rainfall surplus was in July (+27 mm), August (+24 mm), and December (+71 mm) while deficit - in October (-35 mm) and November (-52 mm), others – close to average perrenial. In 2012 rainfall surplus was in October (+41 mm), deficit - in March (-36 mm) and September (-80 mm) while others – close to average (Laukuva meteorological station).

Four calcerous liming materials of local origin were used for the soil liming:

1) dried ground chalk, whiteness class No.1 (80.63 % Ca(Mg)CO$_3$) – finely groud (powdered) liming material;
2) „agralkalkės“ (ag-lime, limestone and calcined lime mixture) (91.45±1.00 % Ca(Mg)CO$_3$) – finely ground (powdered) liming material;
3) crushed dolomite „Dirvitas“ (96.00% CaMg (CO$_3$)$_2$) – crushed liming material, dolomite siftings;
4) “kalktrąšė” (70.87 % Ca(Mg)CO$_3$) – pel-lime (pelleted liming material).

Methodology. Each experimental plot was divided into 5 subplots in area of 5·10 m$^2$,  each subplot was limed with different liming materials. Experiment was performed in four replicates where subplots were layout randomly, and also control subplots without any liming were instaled in each plot.
Amounts of liming materials were calculated according to the liming recommendations of Lithuanian Ministry of Agriculture (Mašauskas et al., 1983): 1) Eutric Albeluvisol (ABe), sandy loam on light loam, acid (pH_KCl 4.27) – 8 t ha⁻¹; 2) Dystric Albeluvisol (ABd), sandy loam on light loam, slightly acidic (pH_KCl 5.82) – 4 t ha⁻¹.

Liming materials were sampled and prepared for analysis according EN 1482:2007. Granulometric composition (particle size) of the crushed dolomite and „kalktrąšė” was determined with dispenser of fertilizer samples „Laborette 26”, and by sieving with different mesh size (1.00 mm, 2.00 mm, 2.50 mm, 3.15 mm, 4.00 mm, 5.00 mm, 5.60 mm) of square sieve openings. Static strength of pellets was determined by static strength meter CPG-1 (measuring range 1-100 N). Bulk density of the liming materials was determined according the mass-volume ratio (ISO 3944:1992).

Reactivity of the liming materials was determined by the potentiometric titration for 10 min with 5M HCl (DIN EN 12945:2008) and calculated as follows:

\[ R = \frac{V_{\text{HCl}} \cdot 14.02 \cdot 100}{m \cdot N} \]

here \( R \) – reactivity, \( \% \), \( V_{\text{HCl}} \) – 5M HCl amount, used for the titration, ml; \( 14.02 \) – mass of the CaO neutralized, g; \( m \) – mass of the lime sample, g; \( N \) – neutralizing index, \% (EN 12945:2008); 100 – factor of the percentage.

Soil pH_KCl (ISO 10390:2005) was monitored for 18 months (from April, 2011 to September, 2012) sampling soil samples from each subplot according ISO 10381-1-4 (2001-2003). Liming efficiency of materials used on it as well as on mobile Al, determined in 1M KCl extract by Sokolov method, was evaluated by mathematical-statistical methods concerning their chemical and physical properties.

**Results of the research**

Chemical and physical properties of the liming materials (Table 1). The determinant substance for the liming materials on soil pH is amount of Ca and Mg carbonates (CaCO_3 and MgCO_3) as in the water almost insoluble carbonates (solubility 0.001 g l⁻¹) react with carbonic acid (H_2CO_3) producing soluble hydrocarbonates Ca(HCO_3)2 and Mg(HCO_3)_2 which hydrolyzes easily forming the soluble hydroxides Ca(OH)_2 and Mg(OH)_2 resulting the increase of Ca and Mg ions in the soil adsorption complex. Moreover, amount of active oxides CaO and MgO derived from carbonates during heating (lime burning) process is relevant because they easily hydrolyzes to hydroxides as their solubility is by two orders of magnitude greater than that of the carbonates. Also, amounts of other elements (Na, K, Fe, S) show the substance ability to increase nutrient content in the soil while amounts of silica and alumosilicates (SiO_2 and Al_2O_3) show the residues.

**Table 1. Chemical and physical properties of the liming materials**

<table>
<thead>
<tr>
<th>Analyte</th>
<th>Chalk</th>
<th>„Agrokalkės“ (ag-lime)</th>
<th>Crushed dolomite „Dirvitas“</th>
<th>Pel-lime „Kalktrąšė“</th>
</tr>
</thead>
<tbody>
<tr>
<td>CaCO_3, %</td>
<td>78.00</td>
<td>87.95</td>
<td>54.00</td>
<td>65.20</td>
</tr>
<tr>
<td>MgCO_3, %</td>
<td>2.63</td>
<td>3.5</td>
<td>42.00</td>
<td>5.67</td>
</tr>
<tr>
<td>CaO, %</td>
<td>nd</td>
<td>49.53</td>
<td>nd</td>
<td>nd</td>
</tr>
<tr>
<td>MgO, %</td>
<td>nd</td>
<td>1.67</td>
<td>nd</td>
<td>nd</td>
</tr>
<tr>
<td>FeO_3, %</td>
<td>0.89</td>
<td>0.43</td>
<td>1.11</td>
<td>1.90</td>
</tr>
<tr>
<td>SO_3, %</td>
<td>0.23</td>
<td>1.21</td>
<td>0.40</td>
<td>3.90</td>
</tr>
<tr>
<td>Na_2O, %</td>
<td>0.12</td>
<td>nd</td>
<td>nd</td>
<td>0.60</td>
</tr>
<tr>
<td>K_2O, %</td>
<td>0.28</td>
<td>nd</td>
<td>nd</td>
<td>3.30</td>
</tr>
<tr>
<td>SiO_2, %</td>
<td>14.76</td>
<td>2.05</td>
<td>2.88</td>
<td>nd</td>
</tr>
<tr>
<td>Al_2O_3, %</td>
<td>1.14</td>
<td>0.20</td>
<td>0.60</td>
<td>nd</td>
</tr>
</tbody>
</table>

Particles size, %:<0.5mm: nd nd 56.80 0.20

0.5-3.15 (2.15; 3.15) mm: nd nd 43.05 99.80 (47.50; 31.40)

>3.15 mm: nd nd 0.15 0.00

Static strenght, N/pellet: nd nd nd 99 (73)**

Density, kg m⁻³: 615 513 1743 1140

Reactivity, %: 94 97 2.8 <0.01 (47)*

*Reactivity of the pelletized and (grounded) pel-lime „Kalktrąšė“; ** Static strenght of pel-lime pellets of 3.15 mm (2.5 mm) fractions

Chalk is a dried fine grounded (powdered) lime mineral calcite (particle size <0.5 mm, density 615 kg m⁻³) containing 78% CaCO_3+2.63% MgCO_3, 1.52% of Fe, Mg, S, Na and K oxides and 15.9% of residuals (Si and Al oxides). It is recommended as additive for the forages as well as liming material, etc. (UAB “Tavilta” http://www.tavilta.lt/products_kreida.html#hre4). Chalk reactivity – 94%.

“Agrokalkės” – limestone and lime powder with particle size <0.5 mm and density 513 kg m⁻³ (87.95% CaCO_3 and 3.5±1.0%MgCO_3) are different from other calcareous materials in that they have 33.36% of active calcium and magnesium oxides (CaO+MgO), that more quickly neutralize acid soil than carbonates, and the first year the effect is gotten. Containing Mg, Fe and S (3.31% of the oxides) complement nutrient amount in the soil. Residual content is...
2.25% (AB “Naujasis kaleitas” http://www.naujajiskalciatus.lt/index_files/Page291.htm). Reactivity of the ag-lime - 97%.

Crushed dolomite „Dirvitas“ (CaMg(CO₃)₂) – crushed liming material, dolomite siftings (particle size < 0.5 mm – 56.8%, 0.5-3.15 mm – 43.05%, >3.15 mm – 0.15 mm; density 1743 kg m⁻³) contains 51% of CaCO₃ and 42% MgCO₃, 1.41% of Fe and S oxides, and 3.48% of residuals (AB „Dolomitas“ http://dolomitas.lt/index.php?page=dirvitas). Crushed dolomite reactivity – 2.8%.

„Kalktrąšė“ – pel-lime (pelleted liming material, particle size ≤0.5 mm – 0.2%, 0.5-3.15 mm – 99.80%, density 1140 kg m⁻³) recommended for the supportive liming of the soils having the tendency to acidify, as their liming effect is slower but longer. Also it is certified as organic fertilizer. The CaCO₃ amounted 65.20%, MgCO₃-5.67% , nutrients (S, K, Na, Fe) oxides content is 9.70% (UAB „Mortar Akmene“ http://mortarakmene.lt/ ). So, the residuals could consist to 19.43%. Reactivity of the pelletted material was near to zero while in the grounded material increased to 47%. Also strength of the pellets varied from 59 to 129 N per pellet in the more coarse fraction (3.15 mm), and from 43 to 103 N per pellet – in the more fine (2.5 mm) fraction.

The effectiveness of liming materials mostly related to the purity referred to as calcium carbonate equivalent (CCE), and to the granuliometric composition (particle size) of the liming material. The CCE is the amount of acid on a weight basis that a given quantity of lime will neutralize when dissolved. It is expressed as a percentage of the neutralizing value of pure calcium carbonate or pure calcite (100 % CCE). Values of the neutralizing index (N) of chalk amount 30-90; calcitic lime 75-100, dolomitic lime – 75, finely ground (powdered) ag-lime – 90-95, fly ash – 43-44, wood ash – 30-70% CCE. Neutralization effect of the liming materials also depend on the granuliometric composition, and it is greater with small particles because of increased total surface area exposed to the soil acidity (Mamo et al., 2003).

Liming effect on soil acidity and mobile aluminium. Effect of liming materials used on acidity of Eutric Albeluvisol was insufficient as the required pHₑₖₛ value of 5.5 for ensuring soil acidity effect on soil ecosystem was not reached (Figure 1, a). This means that recommended value of 8 t ha⁻¹ of pure CaCO₃ (Mašauskas et al.,1983) for the soil investigated was too low and strongly acidified soil should be limed using more liming material. Liming effect on pH of Dystric Albeluvisol was more adequate as pHₑₖₛ reached values of 6.40-6.80 (Figure 1, b). According Eidukeviciene et al. (2010) the best pHₑₖₛ for the yields of the West Lithuanian soil is 6.20 ± 0.20.

The most effective appeared the chalk increasing soil pHₑₖₛ by 1.00 at both Eutric and Dystric Albeluvisols. But its’ effect was very short and unstable as pHₑₖₛ of the Eutric Albeluvisol limed with 6.45 t ha⁻¹ decreased after 18 month while of the Dystric Albeluvisol limed with 3.2 t ha⁻¹ – after 12 months. According Čiuberkienė and Ežerinskas (2000) incorporating in very acid soil 1.9 and 3.3 t ha⁻¹ limestone as well as mineral fertilizers (N₁₅P₉₉K₁₁₄ and N₄₃P₁₃₉K₇₇) the soil reaction returns to initial level after 10 and 15 years; 5.8 t ha⁻¹ – after 20 years, and 14.7 t ha⁻¹ – do not return to its initial level after 4 rotations.

The ag-lime effect was similar to chalk effect as soil pHₑₖₛ increased by 0.60-0.80 but less rapid and more stable than that of the chalk (Figure 1). In the Eutric Albeluvisol the liming effect appeared after 6 months while in the Dystric Albeluvisol – after 2 months. In spite the bigger ag-lime reactivity and amendments of active CaO+MgO the liming effect was less than of the chalk. Hydrated and burnt (quick) limes are quick-acting and have high efficiency, but are caustic and difficult to handle. Lime takes time to neutralize soil acidity. Often as much as six months may be needed before pH changes significantly. Neutralization will be quicker if particle size is small (less than 60 mesh) and the lime is well mixed with the soil. Typically, it will take two to three years to observe the full effect of ag-lime application on soil pH (Mamo et al., 2003). It is known that abundant liming with hydrated lime (active CaO+MgO) has positive influence on soil potential acidity, mobile Al and crop yield for more than 50 years, but the negative effect on soil organic matter and clay particles as leaching can also appear due to long-term liming with it (Eidukeviciene et al., 2010).
The crushed dolomite effect on soil pH\textsubscript{KCl} was less (in 0.05-0.4) and had statistically significant (p<0.05) influence just on the Eutric Albeluvisol after 18 months (Figure 1, a) while no effect on Dystric Albeluvisol (Figure 1, b). This means, that CaCO\textsubscript{3} in the coarse particles needs more acids and more time to be decomposed releasing Ca ions.

Pel-lime had no effect on soil acidity in all the period of 18 month of the exposure (Figure 1). According Murdock (1997) pel-lime (pelleted liming material) is finely ground lime material compressed into pellets or granules to reduce dust associated with very fine particle size. The pellets dissolve in water and the particles quickly disperse and neutralize soil acidity, but the most effective are fine pellets as their have bigger specific surface area. In spite that pel-lime reacts slower than powdered, calcium transfer to the soil sorption complex is faster resulting the more effective neutralization. Our findings contradict to these propositions probably because of the pel-lime „kalkrāšē” coarse pellets (2.15 mm – 47.50%; 3.15 mm – 31.40%) and big residual amount (19.43%) resulting in low reactivity (Table 1).

In summary, effectiveness of liming materials on soil pH\textsubscript{KCl} decreased in order: chalk (80.63% Ca(Mg)CO\textsubscript{3}) > ag-lime (91.45±1.00 % Ca(Mg)CO\textsubscript{3}; 33.36% CaO+MgO) > crushed dolomite (96.00% CaMg (CO\textsubscript{3})\textsubscript{2}) > pel-lime (70.87% Ca(Mg)CO\textsubscript{3}).

The liming efficiency on the mobile aluminium (Al) in the Eutric Albeluvisol is presented in the Figure 2. It can be seen, that in the range of soil acidity pH\textsubscript{KCl} of 4.13 to 4.28 the mobile Al varied from 15.52 to 73.6 mg kg\textsuperscript{-1}. Mobile Al becomes harmful for the plants if its amount in the soil is 10 mg kg\textsuperscript{-1} and decreases the plant growth at the 30-50 mg kg\textsuperscript{-1} (Barabasz et al., 2002; Manea et al., 2011; Krstic et al., 2012). Thereby, in the Eutric Albeluvisol have to be performed liming, firstly, because of harmful amounts of mobile Al resulting in soil bases leaching and acidity increase.

In the Dystric Albeluvisol (pH\textsubscript{KCl} 5.79-5.90) the mobile Al had not been detected. According Mažvila et al. (2008) mobile Al decreases heavily in the soil pH > 5.5 while ranges from 3 to 200 mg kg\textsuperscript{-1} in the acid soils.

Effectiveness of liming materials on the mobile Al decrease was related to that on soil pH\textsubscript{KCl} and to the reactivity. Ag-lime was most effective (99%) following the chalk (97%), crushed dolomite (36%), and pel-lime (15%, statistically insignificant, p>0.05). Ciuberkienė and Ežerinskas (2000) concluded that effect of 1.3 and 1.9 t ha\textsuperscript{-1} limestone on the mobile Al decrease after 20 years was insignificant while of the higher rates it was significant. Also increase in pH by one unit increased leaching of Ca and Mg by 20 %.

Conclusions and recommendations

From the results presented it is obvious, that calculation of the required amount of liming materials according the pure CaCO\textsubscript{3} amount is insufficient as different liming materials has different reactivity and effectiveness related to the origin, chemical composition and particles size of liming materials. When calculating effective calcium carbonate equivalent (ECEE) it is recommended to take into account particles fineness (Mamo et al., 2003):

\[
ECEE = N \cdot F \cdot DM \cdot 1000
\]

(2)

here ECEE – effective calcium carbonate equivalent, %; N – neutralizing index, %, DM – dry matter, %; F - factor of the particle fineness (particle size):

\[
F = (\leq 0.5 \text{ mm,} \%) \cdot 1.0 + (0.5-3.15 \text{ mm,} \%) \cdot 0.4 + (>3.15 \text{ mm,} \%) \cdot 0.1
\]

(3)

Also mixtures of powdered liming materials rich in active CaCO\textsubscript{3} or CaO+MgO and liming materials of coarse granulometric composition and lower reactivity as crushed dolomite or pel-lime are recommended. The powdered liming materials have rapid effect and they are recommended to reach soil pH\textsubscript{KCl} to 6.20 ± 0.20. The coarse liming materials (crushed dolomite, pel-lime) have slower but longer effect and ensure less frequent supportive liming.
Variations in lime requirement may occur depending on past practices such as land use and cropping system, tillage, manure application, mineral fertilizer use. In order to neutralize soil acidification due to 1 t of mineral fertilizers used such coefficients are suggested for the 1 t of pure CaCO₃: ammonium nitrate - 0.74; ammonium sulfate -1.13, urea (carbamide) – 0.90 (Koncius, 2008). When tillage depths are reduced, lime application rates should be reduced proportionately as follows: 5 cm – to recommended value multiply by 0.3; 10 cm – 0.6; 15 cm – 0.9; 25 cm – 1.5. Under no-till systems, lime is surface applied and not mixed with the soil as mixing eventually will occur because of lime falling into cracks, earthworm activity, soil disturbance with planting and other field operations, and irrigation and/or precipitation moving the lime slowly downward (Mamo et al., 2003).

Acknowledgements. The data used from Paulius Sabaliauskas master thesis „The Impact of Different Liming Materials on Potential Soil Acidity and Mobile Aluminium“. Aleksandras Stulgiskis University, K., 2013.

References

The Influence of Universal Bioorganic Nano Fertilizer NAGRO on Spring Barley Crop Productivity

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Aleksandras Stulginskis University, Lithuania

Abstract

Fertilizing field experimentation was carried out in 2012, at the Experimental station of Aleksandras Stulginskis University. Spring rape, spring barley plus under-crop, perennial grass 1 years of using, winter wheat are grown in four-field rotation of crops. Purpose of the experiment was to evaluate the influence fertilizer on spring barley with bioorganic universal nano fertilizers NAGRO and $N_60P_60K_70$. Spring barley breed 'Luokė' was used for the experiment. The effectiveness of $N_60P_60K_70$ and bioorganic universal nano fertilizers NAGRO on spring barley crop was investigated in the experiment. The research showed that $N_60P_60K_70$ and Bioorganic universal nano fertilizers NAGRO had positive effect on the yield of spring barley 'Luokė'. Grain yield increased from 8.8 % to 18.8 % and straw yield - from 10.5 % to 25.5 % when comparing with the control. Best yields were obtained when fertilizing with $N_60P_60K_70$ and bioorganic universal nano fertilizers NAGRO 1 l ha$^{-1}$ and sprayed twice. When fertilizing with $N_60P_60K_70$ and Bioorganic universal nano fertilizers NAGRO 11 ha$^{-1}$ and sprayed twice the rate of crude protein content in grains increased by 0.51 %. Grain quality was better in 2012, when grain proteins up to 10.32 %. NEM controls the maximum number of fields from 77.79 to 78.22%, oil from 2.04 to 2.12 %. Investigated potassium fertilizer and their combinations with when fertilizing with $N_60P_60K_70$ and bioorganic universal nano fertilizers NAGRO 11 ha$^{-1}$ and sprayed twice. Investigated $N_60P_60K_70$ fertilizer and Bioorganic universal nano fertilizers NAGRO 11 ha$^{-1}$ and sprayed twice 1000 seed weight increased from 55.7 to 57.3 g, increase a significant impact 80.0 – 92.8 % on germination 92.5 – 95.8%. Key words: spring barley, fertilizers, yield, chemical composition, bioorganic universal nano fertilizer NAGRO.

Introduction

Spring barley - one of the oldest spring crops in the world. This is one of the most important spring crops according to Lithuanian conditions. They are grown for food, feed and industry. The largest barley grain (approximately 70-75 percent) is consumed as a feed. It's a good concentrated feed, suitable for all types of livestock. Barley straw and chaff are also used for feed and bedding. Grains are widely used in beer, alcohol, textile, confectionery, pharmaceuticals, varnishes, leather and beer industry (Čaikauskas, 1995; Jovaïšienė, 1994; Lazauskas, 1998; Muneen, Bopounna 2008).

Barley grown in Lithuania since time immemorial, it is from the Neolithic era. A number of barley grains, preserved from the I - IV century, were found in mounds (Tindžiulis, 1986).

Modern agriculture is difficult to imagine without mineral fertilizers. Fertilizers improving soil physical, chemical and biological properties increase the yield and improve its quality. The plant nutrients in the soil are constantly changing (Janusauskaite, Ciuberkis, 2010). Some of their uses plants, other are washed out by water, a significant proportion is consumed by soil microorganisms. Plants should receive sufficient amount of all essential nutrients; fertilizing is one of the most important stages (Onaitis, 1989; Kučinskas et al., 1999).

The crop growing season is short and they are demanding a high nutrition. Fertilization is more effective when fertilizer rate and ratio of nutrients items is optimal, when applied locally, and when they are added additionally. Additional fertilization is an effective tool for improving the quality of the harvest, especially in light soils where nutrients are easily leached to deeper soil layers. Additional fertilization method usually is determined by the method of cultivation and fertilizer type (Onaitis, 1989; Kučinskas et al., 1999; Kutra, Aksomatiene, 2003).

Fertilization of plants through the leaves has a number of advantages: it is possible to regulate plant growth and development, taking into account the weather conditions and the condition of the plants themselves, can quickly remove the plant physiological disorders, with nutrient deficiency, or when the soil is nutrient chemical, biological binding or blocking (Delin et al., 2005, Doltra et al., 2011). The majority of applications in these areas have focused on the significance of the nanomaterials for improved efficiency and productivity. These materials are also used in agriculture production and crop protection (Nair et al., 2010; Khot et al., 2012). Many studies have shown that fertilization of plants through the leaves increase yields generally by 5-10 percent, the data obtained from a number of field crops (Staugaitis, 2004).

Carried out field fertilization experiments have been used in the main standard bulk fertilizer ammonium nitrate fertilizer $N_{60}$, $P_{60}$ granular superphosphate, potassium salt of $K_{70}$ and the newly explored additional fertilizer spraying extent bio-organic fertilizer universal nano NAGRO.

Standard bulk fertilizer ammonium nitrate $N_{60}$, granular superphosphate $P_{60}$, potassium salt $K_{70}$ and the newly investigated universal bioorganic nano fertilizer NAGRO for additional spraying were used for the main fertilization in field experiments.

Due to a lack of phosphorus and potassium slows plant growth, they are developing badly. Potassium stimulates photosynthesis, carbohydrates and vitamins macromolecular synthesis, improves the metabolism of water in the cell. Potassium does not contain in enzymes, but it is necessary as a catalyst in enzyme activity. Crops, rich in potassium are more resistant to drought, low temperatures. When it is missing, the leaves edges start dry (Čaikauskas, 1995).

The deficiency of microelements in the soil causes a variety of physiological plant diseases. Boron plays an important catalytic role. Manganese deficiency in plants decrease amount of chlorophyll, the leaves turn white, yield goes down and even plant can die. Magnesium - an integral part of chlorophyll and essential element of photosynthesis. If it lacks, decreases of photosynthesis, leaf growth, leaf spots occur, which slows plant growth and reduces yield (Kučinskas et al., 1999; Čaikauskas, 1995).
Nanoscale science and nanotechnology have been demonstrated to have great potential in providing novel and improved solutions to many grand challenges facing agriculture and society today and in the future (Chen, Yada, 2011). Universal bioorganic fertilizer nano NAGRO was used for additional spray fertilization through the leaves. This is an environment safe product, made from an organic substrate with micro-, macro-, mezo-elements and bioactive materials, designed for all types of agricultural, ornamental crops, forest, parks green areas in various types of soils. Application of fertilizers increases yields, enhances plant immunity, protects against stress (drought, frost, impact of pesticides) and diseases, shortens the ripening period, improves quality of products and fruit storage period. There are different opportunities for the application: as a water solution for seed treatment before sowing, leaf processing, root irrigation. Fertilizer composition is as following: humus extract, at least 0.2% of humic and fulvic acids, total nitrogen (N) not less than 0.015%, total potassium (K) not less than 0.02, total phosphorus not less than 0.002%. It is a dark brown liquid with characteristic odor, pH 7.0 to 9.9.

The research object - spring barley fertilized with ammonium nitrate N46, granular superphosphate P60, potassium salt K70 and newly investigated universal bioorganic nano fertilizer NAGRO for additional spraying.

The research aim - to investigate N46P60K70 fertilizers and it combinations with universal bioorganic nano fertilizer NAGRO on spring barley.

The research objectives:
1) to determine the influence of N46P60K70 fertilizers and it combinations with universal bioorganic nano fertilizer NAGRO on spring barley yield;
2) to identify and evaluate the influence of N46P60K70 fertilizers and it combinations with universal bioorganic nano fertilizer NAGRO on spring barley grain qualitative characteristics;
3) to implement an economic evaluation of N46P60K70 fertilizers and it combinations with universal bioorganic nano fertilizer NAGRO application on spring barley.

Material and methods

Experiment location and soil characteristics. Experiment was carried out at ASU Research station in 2011 - 2012. The soil ephipoglycic luvisol (Calc (ar) i-Épiphoglycic Luvisol) - IDg8-k (LVg-pw-cc), soil texture - loam on moderate to heavy loam. Plowing layer of the soil close to neutral (pH 6.8 to 7.2), basic, with medium humus content, medium or even large amounts of phosphorus and medium potassium, boron, magnesium and cuprum, low zinc and molybdenum, enough of manganese.

Soil samples were taken according to sampling methodology, analysis of soil agrochemical properties carried out at Agrochemical Research Centre of Lithuanian Institute of Agriculture.

Experiment scheme and research methods. Field experiment carried out at Aleksandras Stulginskis University Research station in 2011 - 2012 in accordance to the scheme:

1. Control (unfertilised)
2. N46P60K70
3. N46P60K70 NAGRO + 0.25 l ha⁻¹, sprayed 1 time
4. N46P60K70 NAGRO + 0.5 l ha⁻¹, sprayed 1 time
5. N46P60K70 NAGRO + 0.25 l ha⁻¹, sprayed 2 times
6. N46P60K70 NAGRO + 0.5 l ha⁻¹, sprayed 2 times

Experiments carried out in three replications, the total field area of 56 m² (14 m x 4 m), and accounting - 26.4 m² (12 m x 2.2 m).

Total nitrogen content in spring barley grain determined by the Kjeldahl method, green protein calculated by multiplying the total nitrogen content by a coefficient of 6.25. Humus estimated by the Tyurin method, mobile phosphorus and potassium – A-L method, pH – in 1 N KCl extract, mineral nitrogen – in 1 N KCl extract, load (10 g) and the solution ratio was 1:2.5 (Tarakanovas et al., 2003).

Field test results of variance analysis. LSD₀.⁰⁵ is a significant difference in threshold 95 percent probability level. Harvest records taken 21nd of August, 2011 - 2012. Barley grain and straw samples for product quality analyzes were collected from each field separately. The market and harvest purchase prices, production costs used for economic calculations reflect to ASU Research station actual production costs.

Kaunas meteorological observatory meteorological data used for the description of meteorological conditions. Agrotechnical measures and timing. Spring barley was sown 22nd of April, 2012, seed rate 170 kg ha⁻¹, variety ‘Luokė’. Main fertilization N46P60K70, superphosphate (Ca(H₂PO₄)₂*CaSO₄), ammonium nitrate (NH₄NO₃), potassium fertilizers were applied before sowing. Later, twice, carried out additional fertilization with NAGRO fertilizer through the leaves. Water rate for solution – 400 l ha⁻¹. Plant protection measures were not used. Grain dried to 14%, cleaned and estimated yield in t ha⁻¹, and investigated their chemical composition at ASU Experimental station with infrared analyzer.

Data statistically evaluated using analysis of variance ANOVA program (Tarakanovas et al., 2003, Raudonius, 2008).

Meteorological conditions. Spring was early and warm in 2012. In April, the weather conditions for the sowing and seed germination was not very favorable. In April, the average precipitation was 16.4 mm less than the multi-annual average. The highest average daily temperature of the month was in the third decade (14.0° C), by 7.8°C higher than the multi-annual average, but there were lack of moisture for seed germination. In May, there was an average of warm
weather. The average daily temperature varied only by 0.1°C from the average perennial. The largest amount of precipitation fell in the second decade - 22 mm. However, the monthly rainfall in a little different from the multi-annual average - 47.0 mm. Development conditions were optimal. June was warm, the highest air temperature fixed at the beginning of the month, when the average daily temperature was 21.2°C. Monthly average temperature was by 2.6°C higher than the multi-average. During the month fell 54.0 mm of rainfall, it is 15.1 mm less than the multi-annual average. The soil was dry, was hard for the plants to take nutrients from the soil and it worth to apply spraying NAGRO solution through the leaves. July was the hottest month of the summer months. The soil was wet, during the month fell 146 mm of rainfall. Most rainfall (67.0 mm) fell on the first decade; the average monthly mean was 62.6 mm higher than the average multi-annual precipitation. Rainy weather started in August, although still warm and sunny. During the month fell even 152.0 mm rainfall, 82.2 mm. more for the multi-average. The average monthly temperature was by 0.8°C higher than the multi-annual average.

Research results and analysis

Influence of N60P60K70 and universal bioorganic nano fertilizer NAGRO on spring barley grain yield.

According to Table 1, we see that the minimum grain yield of spring barley in 2012 received from the control plots. All experiment plots, where it was used N60P60K70 and universal bioorganic nano fertilizer NAGRO were obtained significant yield increase. Spring barley yield increased by 6.8% - 16.3%, or from 0.39 to 0.93 t ha⁻¹ comparing with control.

Table 1. Influence of N60P60K70 and universal bioorganic nano fertilizer NAGRO on spring barley grain yield

<table>
<thead>
<tr>
<th>No.</th>
<th>Variants</th>
<th>Grain yield t ha⁻¹</th>
<th>Increase of yield t ha⁻¹</th>
<th>Increase of yield %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Control (unfertilized)</td>
<td>5.69</td>
<td>-</td>
<td>100.0</td>
</tr>
<tr>
<td>2.</td>
<td>N60P60K70</td>
<td>6.07</td>
<td>0.39</td>
<td>106.8</td>
</tr>
<tr>
<td>3.</td>
<td>N60P60K70+ NAGRO 0.25 ha⁻¹ sprayed 1 time</td>
<td>6.27</td>
<td>0.59</td>
<td>110.3</td>
</tr>
<tr>
<td>4.</td>
<td>N60P60K70+ NAGRO 0.5 ha⁻¹ sprayed 1 time</td>
<td>6.40</td>
<td>0.71</td>
<td>112.5</td>
</tr>
<tr>
<td>5.</td>
<td>N60P60K70+ NAGRO 0.25 ha⁻¹ sprayed 2 times</td>
<td>6.47</td>
<td>0.78</td>
<td>113.7</td>
</tr>
<tr>
<td>6.</td>
<td>N60P60K70+ NAGRO 0.5 ha⁻¹ sprayed 2 times</td>
<td>6.61</td>
<td>0.93</td>
<td>116.3</td>
</tr>
<tr>
<td></td>
<td>LSD0.05</td>
<td>0.224</td>
<td></td>
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</tbody>
</table>

The minimum premium grain yield in 2012 was fertilizing only with N60P60K70. Premium grain yield in comparison with the control received 0.39 t ha⁻¹ (6.8%). Combination, having the most affecting impact on barley yield was N60P60K70 + NAGRO 0.51 ha⁻¹ sprayed 2 times (variant 6). There spring barley yield was 6.61 t ha⁻¹. Investigations were carried out with sufficient precision, as the test accuracy (Sx%) was 1.23%. Influence on grain yield had increase of NAGRO spray rate and number of spraying times. Higher yield was obtained by spraying NAGRO 0.5 ha⁻¹ twice.

Influence of N60P60K70 and universal bioorganic nano fertilizer NAGRO on spring barley straw yield

Research carried out in 2012 shows (Table 2), that in all experiment plots, where it was used N60P60K70 and universal bioorganic nano fertilizer NAGRO, received significant spring barley straw premium yield. Spring barley straw yield increased by 9.5% - 17.6%, or from 0.38 t ha⁻¹ to 0.70 t ha⁻¹ comparing with control.

Table 2. Influence of N60P60K70 and universal bioorganic nano fertilizer NAGRO on spring barley straw yield

<table>
<thead>
<tr>
<th>No.</th>
<th>Variants</th>
<th>Straw yield t ha⁻¹</th>
<th>Increase of yield t ha⁻¹</th>
<th>Increase of yield %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Control (unfertilized)</td>
<td>3.98</td>
<td>-</td>
<td>100.0</td>
</tr>
<tr>
<td>2.</td>
<td>N60P60K70</td>
<td>4.36</td>
<td>0.38</td>
<td>109.5</td>
</tr>
<tr>
<td>3.</td>
<td>N60P60K70+ NAGRO 0.25 ha⁻¹ sprayed 1 time</td>
<td>4.46</td>
<td>0.48</td>
<td>112.0</td>
</tr>
<tr>
<td>4.</td>
<td>N60P60K70+ NAGRO 0.5 ha⁻¹ sprayed 1 time</td>
<td>4.60</td>
<td>0.62</td>
<td>115.5</td>
</tr>
<tr>
<td>5.</td>
<td>N60P60K70+ NAGRO 0.25 ha⁻¹ sprayed 2 times</td>
<td>4.61</td>
<td>0.63</td>
<td>115.9</td>
</tr>
<tr>
<td>6.</td>
<td>N60P60K70+ NAGRO 0.5 ha⁻¹ sprayed 2 times</td>
<td>4.68</td>
<td>0.70</td>
<td>117.6</td>
</tr>
<tr>
<td></td>
<td>LSD0.05</td>
<td>0.268</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The minimum premium straw yield was fertilizing only with N60P60K70, comparing all experiment plots. Premium straw yield in these variants as compared with the control, was 0.38 t ha⁻¹ (9.5%). Combination, having the most affecting impact on barley yield was N60P60K70 + NAGRO (variant 6). Spring barley grown 4.68 t ha⁻¹ of straw yield, or 0.70 t ha⁻¹ (17.6%) of premium yield.

Influence of N60P60K70 and universal bioorganic nano fertilizer NAGRO on spring barley 1000 seed weight, sprouting energy and germination

One of the yield quality indicators is 1000 seed weight. 1000 seed mass increased significantly under the application of N60P60K70 and universal bioorganic nano fertilizer NAGRO. Table 3 shows that the lowest 1000 seed weight of spring barley (55.7 g) was in the control plot. The maximum weight of 1000 seeds received from variant 5 and 6, where were applied N60P60K70 and universal bioorganic nano fertilizer NAGRO both, with different concentrations of NAGRO (57.3 g).
the plant species and the characteristics of the variety, growing conditions. The literature indicates that the barley grains products. Cereal grain quality is determined by proteins and starch. Various organic compounds in plants depends on calculated according to the bio-organic fertilizer NAGRO (45 Lt ha⁻¹).

Influence of N₆₀P₆₀K₇₀ and universal bioorganic nano fertilizer NAGRO on spring barley grain chemical composition

Crop production measured by a variety of organic compounds, so they determine the nature and use of the products. Cereal grain quality is determined by proteins and starch. Various organic compounds in plants depends on the plant species and the characteristics of the variety, growing conditions. The literature indicates that the barley grains has on average 11% protein, 75% nitrogen-free extractives (NEM), 5% of fiber, 2% of fat and 2.5% of ash (Kucinskas et al., 1999). Plant nutrition conditions are important for yield and yield quality. For example, plants rich fertilized with nitrogen, accumulates more protein; receiving a large dose of potassium - synthesize more carbohydrates (Kucinskas et al., 1999). Research data shows that fertilization with N₆₀P₆₀K₇₀ and universal bioorganic nano fertilizer NAGRO changed the spring barley grain chemical composition (Table 4).

<table>
<thead>
<tr>
<th>No.</th>
<th>Variants</th>
<th>1000 seed weight</th>
<th>Sprouting energy %</th>
<th>Germination %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Control (unfertilized)</td>
<td>55.7</td>
<td>80.0</td>
<td>92.5</td>
</tr>
<tr>
<td>2.</td>
<td>N₆₀P₆₀K₇₀</td>
<td>56.8</td>
<td>89.5</td>
<td>92.5</td>
</tr>
<tr>
<td>3.</td>
<td>N₆₀P₆₀K₇₀+ NAGRO 0.25 ha⁻¹ sprayed 1 time</td>
<td>57.0</td>
<td>90.3</td>
<td>93.1</td>
</tr>
<tr>
<td>4.</td>
<td>N₆₀P₆₀K₇₀+ NAGRO 0.5 ha⁻¹ sprayed 1 time</td>
<td>57.2</td>
<td>90.8</td>
<td>93.4</td>
</tr>
<tr>
<td>5.</td>
<td>N₆₀P₆₀K₇₀+ NAGRO 0.25 ha⁻¹ sprayed 2 times</td>
<td>57.3</td>
<td>91.9</td>
<td>95.0</td>
</tr>
<tr>
<td>6.</td>
<td>N₆₀P₆₀K₇₀+ NAGRO 0.5 ha⁻¹ sprayed 2 times</td>
<td>57.3</td>
<td>92.8</td>
<td>95.8</td>
</tr>
</tbody>
</table>

Table 3. Influence of N₆₀P₆₀K₇₀ and universal bioorganic nano fertilizer NAGRO on spring barley 1000 seed weight, sprouting energy and germination

Table 4. Influence of N₆₀P₆₀K₇₀ and universal bioorganic nano fertilizer NAGRO on spring barley grain chemical composition

The average data (Table 5), shows that the fertilizer N₆₀P₆₀K₇₀ and universal bioorganic nano fertilizer NAGRO increased green protein content in spring barley grain. Most of all - 10.37% - of green protein accumulation in spring barley grain was observed fertilizing with fertilizers N₆₀P₆₀K₇₀ and universal bioorganic nano fertilizer NAGRO 0.5 ha⁻¹ 2 times. The green protein content considerably increased in comparison with the control (0.31 to 0.56 percent). Protein content in spring barley grain was higher in almost all cases, comparing with the control. NEM increased 77.86 - 78.47 percent, fat 1.99 - 12.2 percent, fiber 5.52 to 5.66 percent.

Economic evaluation of the application N₆₀P₆₀K₇₀ and universal bioorganic nano fertilizer NAGRO for spring barley

Primary agricultural production, economic impact key indicators are agricultural gross output and net income. If the total output or yield depends on agrotechnical practices, production is affected by profits and sales, the buying price and so on. (Treinys M., 1982).

Examining the ways of economic indicators for fertilization ways, were used additional costs: fertilizer value, including its transport to the farm and the storage conditions, fertilization costs, the coasts of premium yield harvesting, additional indirect costs. Control is taken as a base rate (reference point).

Economic impact indicators shall be calculated after calculating of the production effect. They are expressed in terms of agricultural value, or part of it. The most commonly used indicators of economic effect: gross output value and net income. Gross output value is calculated by multiplying the quantity of harvested yield from the unit purchase price. Net income is calculated from the gross production value minus the cost of production.

Table 6. Economic evaluation of the application N₆₀P₆₀K₇₀ and universal bioorganic nano fertilizer NAGRO for spring barley according to grain yield

<table>
<thead>
<tr>
<th>Applied biological preparat</th>
<th>Premium yield t ha⁻¹</th>
<th>Premium yield value Lt ha⁻¹</th>
<th>Additional production costs Lt ha⁻¹</th>
<th>Additional gross profit Lt ha⁻¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control (unfertilized)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>N₆₀P₆₀K₇₀</td>
<td>0.39</td>
<td>273.0</td>
<td>84.9</td>
<td>188.10</td>
</tr>
<tr>
<td>N₆₀P₆₀K₇₀+ NAGRO 0.25 ha⁻¹ sprayed 1 time</td>
<td>0.59</td>
<td>413.0</td>
<td>41.25</td>
<td>371.75</td>
</tr>
<tr>
<td>N₆₀P₆₀K₇₀+ NAGRO 0.5 ha⁻¹ sprayed 1 time</td>
<td>0.71</td>
<td>497.0</td>
<td>52.5</td>
<td>414.5</td>
</tr>
<tr>
<td>N₆₀P₆₀K₇₀+ NAGRO 0.25 ha⁻¹ sprayed 2 times</td>
<td>0.78</td>
<td>546.0</td>
<td>82.5</td>
<td>441.0</td>
</tr>
<tr>
<td>N₆₀P₆₀K₇₀+ NAGRO 0.5 ha⁻¹ sprayed 2 times</td>
<td>0.93</td>
<td>651.0</td>
<td>105.0</td>
<td>546.0</td>
</tr>
</tbody>
</table>

The core of economical evaluation is necessity to compare technologies and the allocation of resources used to their benefit or detriment. The result can be both positive and negative. Each composite indicator shall be expressed in monetary terms. In this experiment, the premium yield value was calculated by multiplying yield and spring barley price. The average 2012 spring barley purchase price was 700 Lt per ton of seeds. Additional production costs are calculated according to the bio-organic fertilizer NAGRO (45 Lt ha⁻¹) and the spray works (30 Lt ha⁻¹) prices.
Additional gross profit calculating the yield value and the additional production costs. The evaluation of bio-organic fertilizer NAGRO efficiency shows that the spring barley seed yield varied from 0.39 to 0.93 t ha⁻¹. The maximum premium yield received after the application of universal bioorganic nano fertilizer NAGRO 0.5 l ha⁻¹ product solution, spraying twice. Spring barley, sprayed with fertilizer NAGRO 0.5 l ha⁻¹ solution twice gave a 0.93 t ha⁻¹ premium yield compared to spring barley, sprayed once. Premium yield value was greater than the additional costs. Premium yield of spring barley, sprayed with fertilizer NAGRO 0.5 l ha⁻¹ solution twice was higher 238.0Lt ha⁻¹ higher than the sprayed once.

The largest additional production costs were spraying spring barley twice with fertilizer NAGRO 0.5 l ha⁻¹ solution twice - 105.0 Lt ha⁻¹. However, the cost of production minus produced the highest total profit of 546 Lt ha⁻¹ or 174.25 Lt ha⁻¹ higher than plants sprayed once.

Conclusions

Significant premium yield obtained everywhere, where it was used N₀₅P₀₅K₇₀ and universal bioorganic nano fertilizer NAGRO. Compared with control, spring barley yield increased by 6.8% - 16.3%, or from 0.39 to 0.93 t ha⁻¹ and straw yield increased from 0.38 t ha⁻¹ to 0.70 t ha⁻¹ or from 9.5% to 17.6%.

The best yield of spring barley grain and straw received after application of N₀₅P₀₅K₇₀. Observed positive influence of combination N₀₅P₀₅K₇₀ + NAGRO 0.5 l ha⁻¹ (sprayed 2 times) on spring barley yield. Spring barley grown 6.61 t ha⁻¹.

The smallest premium yield of spring barley received after application only N₀₅P₀₅K₇₀.

Fertilization with N₀₅P₀₅K₇₀ and universal bioorganic nano fertilizer NAGRO solutions significantly increased yield of spring barley grain and straw and improved grain quality.

Application of N₀₅P₀₅K₇₀ and universal bioorganic nano fertilizer NAGRO positively influenced on 1000 grain weight, sprouting energy and germination.

Application of N₀₅P₀₅K₇₀ and universal bioorganic nano fertilizer NAGRO is economically beneficial because it gave the highest profit compared with other options, 546 Lt ha⁻¹.

For additional foliar fertilization the most economically profitable application of universal bioorganic nano fertilizer NAGRO twice 0.5 l ha⁻¹.

References

Sexual Dimorphism in the Body and Skull of the Pine marten (M. martes) and Stone marten (M. foina) from Lithuania

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Aleksandras Stulginskius University, Lithuania

Introduction

The specific nature of hunting martens and formulating the study samples ordain that the samples of the craniometric data are often smaller than the samples of the morphometric data. Therefore, the problem concerning the credibility of the statistical conclusions on the dimorphism of martens based on the craniometric data remains. To solve this problem, it is imperative to firstly improve the research database of both species of martens residing in Lithuania. The first sexual dimorphism data of the pine martens residing in Lithuania were announced by S. Maldžiūnaitė (1959). Having studied the biology of the pine martens, she determined that compared to the females of the pine martens, the adult males differ in terms of size, weight and body measurements. The goal of this work was to determine the sexual dimorphism of the subadult pine and stone martens living in Lithuania. 32 pine martens and 30 stone martens were studied. It was determined that the subadult males of both species of martens were heftier than the subadult females in terms of the morphometric data of their bodies; however, their sexual dimorphism was not manifested as strongly. The males of both species of martens were slightly bulkier than the female specimens and the statistically significant differences were determined in the body mass, girth, fur weight and tail length data (p = 0.1). Following 14 distinct measurements of the skulls of both species of subadult martens, it was defined that the sexual dimorphism of martens was only faintly indicated by the craniometric data. The following data were deemed to have statistically reliable differences: (PtL), (MxtL), (CbL) and (MnbL) of the pine marten and (BchBf), (MxtL), and (MnbBf) of the stone marten (p<0.1). The sexual dimorphism of both species of marten was statistically reliably attested only by the length of maxillary tooth row (MxtL) out of all the craniometric data of skull measurements.

Keywords: pine marten, stone marten, subadult, sexual dimorphism, morphometry, craniometry, Lithuania.

Introduction

Sexual dimorphism is one of the key sexual selection factors giving explanation to the continued survival of subspecies. The morphometric data of the body are highly significant for determining and defining the differences between males and females of the species, i.e. sexual dimorphism, which is a sexual selection factor. The sexual dimorphism of mammals manifests in different morphometric parameters and has become the research object for many scientists. When studying the biology of mammals, the Bergmann's rule applies. According to this important old rule, all individuals of warm-blooded vertebrates hailing from colder environments are bulkier in size compared to their “congeners” in the warmer regions (Bergmann, 1847). This rule was reformed by a German scientist Rensch (1938), who determined (1950) that males are larger individuals in general and this type of dimorphism was better expressed within the large-sized animal species. This correlation was called the Rensch’s rule and was widely researched resulting in explanations to many of the questions arisen in regards with the formation of certain species during the evolution. The rule was confirmed by researches on primates (Clutton–Brock et al., 1977), turtles (Berry and Shine, 1980), water striders (Andersen, 1997), mites (Colwell, 2000), salmonidae, and birds (Payne, 1984; Székely, 2004). The morphometric studies of the body, skull, internal organs and skeleton of all animals are essential in describing and classifying certain animal species.

Lithuania is home to the following two species of martens: pine marten (Martes martes L.) and stone marten (Martes foina Erxleben 1777), both of which belong to the same Mustelidae (Mustelidae) family. The morphological studies of martens are important because both species indeed have a lot of morphological similarities; however, there are several differences as well, starting with the distinct habitats of each different species and their ecology. Due to the large variety of habitats the nutritional peculiarities, food preferences and the size of prey differ in cases of distinct marten species – the pine or stone martens, respectively. The said factors may also hold influence over the morphophysiological differences of martens. Even though presumably the size of the prey caught by the martens differs in respect to their sex, it does not always occur that the male martens prey on larger animals than the females. The average prey size of martens is distinct among separate populations rather than the sexes (p = 0.54) (Zalewski et al., 2007). Curiously, in respect to the sexual dimorphism of martens and based on the body size parameters, it was determined that the movement speed of the males and females and their territory of prey hunting were similar during all the seasons of the year. It was only in spring that the females nursing their young moved faster when looking for food (0.77 km*h⁻¹ in average) compared to the females who had no offsprings. Therefore, these data show that neither the composition of food, the size of the caught prey nor the behavior in catching prey explains the reasons of the sexual dimorphism of martens (Zalewski et al., 2004).

As mentioned before, the most prevalent fact is that the females of most mammal species are smaller in size than the males. Also, many of the comparative scientific studies state that the body length of adult females and males are determined genetically (Fairbairn, 1997; Teder and Tammaru, 2005; Dale et al., 2007). Several scientists believe that the lower morphological parameters of female animals are related to the higher energy losses during the stage of reaching sexual maturity compared to the males and the cyclic periods of producing the gametes and ovum (Walker and MacCormik, 2004).
The first sexual dimorphism data of the pine martens residing in Lithuania were announced by S. Maldžiūnaitė (1959). Having studied the biology of the pine martens, she determined that compared to the females of the pine martens, the adult males differ in terms of size, weight and body measurements (Table 1).

Table 1. Sexual dimorphism of pine martens (M. martes) according to the morphometric data

<table>
<thead>
<tr>
<th>Gender</th>
<th>Body mass, g</th>
<th>Fur weight, g</th>
<th>Body length, cm</th>
<th>Tail length, cm</th>
<th>Hind leg length, cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Males</td>
<td>1246.7</td>
<td>187.8</td>
<td>45.3</td>
<td>22.9</td>
<td>8.95</td>
</tr>
<tr>
<td>Females</td>
<td>915.7</td>
<td>147.2</td>
<td>42.3</td>
<td>21.4</td>
<td>8.09</td>
</tr>
</tbody>
</table>

After summarizing the provided literature sources, data were found proving that the pine martens living in Europe are sexually dimorphic; however, it is yet to be determined whether or not this could be related to the physiological or geographical features of the habitat of the marten population (Reig, 1992).

The goal of this study is to determine the sexual dimorphism of the subadult pine and stone martens living in Lithuania.

Research Methods

The martens were hunted for the research purposes in the territories of Kaunas, Šiauliai, Jonava, Šilutė, Vilkaviškis, and Marijampolė Municipalities according to the Hunting Rules of the Republic of Lithuania by using traps, herding with hounds, stalking and hunting with beaters. The researches were carried out during 2010–2013 in the Game Management Laboratory of the Forest Biology and Silviculture Institute of the Faculty of Forest Sciences and Ecology of Aleksandras Stulginskis University. 32 pine martens (M. martes) and 30 stone martens (M. foina) were studied. All martens was of subadult age group recognized on noticeable development of crista sagittalis externa and tooth wear degree.

The morphometric measurements of martens were performed after hunting them down prior to the stiffening of the body or after rigor mortis (rigor mortes). The martens were laid on their sides and their soft body area was measured along the body curves. The measuring layout is presented in Fig. 1. The abbreviations of the measurements are also provided below.

Figure 1. Layout for morphometric measurements of the marten body

The following body measurements were performed (in cm): 1 – body length (L) measured from the tip of the snout to the base of the tail; 2 – tail length (C), from the base to the tip of the tail (without fur); 3 – hind leg length (P) measured from the hock joint to the tip of the longest toe (without the claw); 4 – girth (K) measured at the biggest part of the ribcage; 5 – ear length (A) measured from the depression of the bottom part of the pinna to the ear tip (without fur).

The body mass (Q) and fur weight (Q1) of the martens were determined by weighing (possible error of 0.01 kg) by using the SI–6002 laboratory balance (Denver Instruments, Germany).

Due to various head injuries, not all of the specimens of the hunted down martens could be used in craniometric studies.

The skulls of the martens were prepared for the craniometric studies as follows: the heads were separated from the bodies and boiled in water, followed by soft tissue removal and drying. After that it was 14 different craniometric measurements determined as presented in Fig 2.
Research Results

The literature analysis showed that the sexual dimorphism of mammals was especially well manifested in the parameters defining body size. The sexual dimorphism of martens is determined by the data of body and skull measurements. During her studies of the Lithuanian pine marten biology in the fifties, Maldžiūnaitė (1959) determined that adult pine marten males differ in size, weight and body measurements compared to the female specimens.

Following this research, the results of the sexual dimorphism of subadult martens according to the morphometric and craniometric data were presented in Tables 1 and 2, where: n – variable’s sample size, x – variable mean, S – variable’s standard deviation.

Rudimentary analysis of the presented data showed the differences of mean body measurements of females and males of both marten species according to all the variables which in turn encouraged further study of the differences in detail. A statistical hypothesis verification method was employed to determine the sexual dimorphism of martens in such a way that it summarized the situation officially. Due to the lack of data and the presence of complex normal distribution of variables, the comparative procedure t-test for small sample size of two mean values and distinct dispersions was selected. (Data Analysis Add-In of the Microsoft Excel application, the T–Test tool: two samples assuming unequal variances).

According to each variable a null hypothesis was formulated $H_0 : \mu_M = \mu_F$ (the variable mean of male (M) is not lower than the variable mean of female (F)) as well as an alternative hypothesis $H_a : \mu_M < \mu_F$ or $H_a : \mu_M < \mu_F$. The $H_0$ hypothesis was verified according to the Student’s t-test $T = (x_M - x_F)/SE$, which has the Student’s probability distribution with $DF$ degrees of freedom. Here: $x_M$ – variable mean in male sample, $x_F$ – variable mean in female sample, $SE$ – standard deviation of the estimate of joint population mean $SE = \sqrt{S_M^2/n_M + S_F^2/n_F}$, number of degrees of freedom $DF = (S_M^2/n_M + S_F^2/n_F)/(S_M^2/n_M)^2/(n_M-1) + (S_F^2/n_F)^2/(n_F-1)$. Based on the formulation of the $H_0$ and $H_a$ hypotheses, it is obvious that the $p$-value was determined by the critical one-tail (right or left) test which is more favorable than the critical two-tail in case of acknowledging the significant mean difference. $P$-value defined the acceptability degree of the null hypothesis. If the $p$-value was lower than the significance level ($p<0.1$), i.e. probability of error, the null hypothesis was rejected and an alternative one was accepted. The $p$-value was provisionally deemed to be the ratio summarizing the marten measurement results.

The calculations presented in Table 2 show that according to all the body parameters the male pine martens are bulkier than the females; however, only several of the parameters show a statistically significant dimorphism of pine martens.
Table 2. Sexual dimorphism of pine martens (M. martes) according to the morphometric and craniometric data

<table>
<thead>
<tr>
<th>Measurements</th>
<th>Females (F)</th>
<th>p value</th>
<th>Males (M)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n x S</td>
<td></td>
<td>n x S</td>
</tr>
<tr>
<td>Body:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L, cm</td>
<td>18 44.14 6.38</td>
<td>0.181</td>
<td>14 45.12 10.78</td>
</tr>
<tr>
<td>C, cm</td>
<td>18 22.06 1.79</td>
<td>0.056</td>
<td>14 22.82 1.68</td>
</tr>
<tr>
<td>Q, kg</td>
<td>13 1.40 0.06</td>
<td>0.045</td>
<td>13 1.56 0.09</td>
</tr>
<tr>
<td>Q1. kg</td>
<td>8 0.17 0.00</td>
<td>0.023</td>
<td>6 0.25 0.01</td>
</tr>
<tr>
<td>A, cm</td>
<td>13 3.25 0.14</td>
<td>0.358</td>
<td>14 3.32 0.32</td>
</tr>
<tr>
<td>K, cm</td>
<td>18 16.78 6.74</td>
<td>0.011</td>
<td>14 18.74 3.79</td>
</tr>
<tr>
<td>U, cm</td>
<td>18 6.44 2.56</td>
<td>0.389</td>
<td>14 6.59 1.83</td>
</tr>
<tr>
<td>Skull:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cbl., mm</td>
<td>16 8.39 0.16</td>
<td>0.072</td>
<td>8 8.20 0.06</td>
</tr>
<tr>
<td>MxtL., mm</td>
<td>16 3.81 0.08</td>
<td>0.365</td>
<td>8 3.75 0.16</td>
</tr>
<tr>
<td>Bcl., mm</td>
<td>16 3.89 0.14</td>
<td>0.368</td>
<td>8 3.84 0.12</td>
</tr>
<tr>
<td>PtL., mm</td>
<td>13 4.25 0.13</td>
<td>0.043</td>
<td>4 3.83 0.12</td>
</tr>
<tr>
<td>RtrW, mm</td>
<td>16 1.56 0.01</td>
<td>0.239</td>
<td>8 1.53 0.01</td>
</tr>
<tr>
<td>EorW, mm</td>
<td>16 4.68 0.11</td>
<td>0.196</td>
<td>8 4.57 0.07</td>
</tr>
<tr>
<td>IorW, mm</td>
<td>16 2.01 0.02</td>
<td>0.258</td>
<td>8 2.08 0.08</td>
</tr>
<tr>
<td>PorW, mm</td>
<td>16 1.93 0.07</td>
<td>0.231</td>
<td>8 1.87 0.02</td>
</tr>
<tr>
<td>MstW, mm</td>
<td>16 3.79 0.05</td>
<td>0.183</td>
<td>8 3.71 0.03</td>
</tr>
<tr>
<td>BcbH, mm</td>
<td>16 3.13 0.06</td>
<td>0.237</td>
<td>8 3.01 0.16</td>
</tr>
<tr>
<td>MxtL., mm</td>
<td>16 3.48 0.04</td>
<td>0.061</td>
<td>8 3.31 0.06</td>
</tr>
<tr>
<td>MnbL, mm</td>
<td>16 5.27 0.09</td>
<td>0.075</td>
<td>8 5.08 0.08</td>
</tr>
<tr>
<td>MnbH, mm</td>
<td>16 2.33 0.03</td>
<td>0.330</td>
<td>8 2.30 0.03</td>
</tr>
<tr>
<td>MntL., mm</td>
<td>16 3.49 0.07</td>
<td>0.462</td>
<td>8 3.49 0.02</td>
</tr>
</tbody>
</table>

The determined *p*-value with a significance level lower than 0.1 showed that the male pine martens were bulkier than the females based on their girth (*p*=0.011), weight of fur (*p*=0.023), tail length (*p*=0.045), and body length (*p*=0.056). The girth of the male pine marten was larger than that of the female by 10.5 %, the fur weight by 32.8 %, the tail length by 3.4 %, and the body length by 2.2 %.

The analysis of the stone marten data according to all the body mass parameters (Table 3) revealed that the male specimens of stone martens were bulkier than the females; however, as in the case of pine martens, only several of the parameters showed a statistically significant sexual dimorphism of the pine martens.

Table 3. Sexual dimorphism of stone martens (M. foina) according to the morphometric and craniometric data

<table>
<thead>
<tr>
<th>Measurements</th>
<th>Females (F)</th>
<th>p value</th>
<th>Males (M)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n x S</td>
<td></td>
<td>n x S</td>
</tr>
<tr>
<td>Body:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L, cm</td>
<td>12 43.20 3.38</td>
<td>0.077</td>
<td>16 44.20 3.67</td>
</tr>
<tr>
<td>C, cm</td>
<td>12 20.01 11.80</td>
<td>0.062</td>
<td>16 21.80 6.26</td>
</tr>
<tr>
<td>Q, kg</td>
<td>11 1.18 0.07</td>
<td>0.017</td>
<td>15 1.41 0.06</td>
</tr>
<tr>
<td>Q1. kg</td>
<td>6 0.15 0</td>
<td>0.017</td>
<td>7 0.19</td>
</tr>
<tr>
<td>A, cm</td>
<td>5 2.30 0.20</td>
<td>0.404</td>
<td>6 2.37 0.19</td>
</tr>
<tr>
<td>K, cm</td>
<td>12 15.1 2.45</td>
<td>0.075</td>
<td>17 16.2 5.31</td>
</tr>
<tr>
<td>U, cm</td>
<td>13 6.52 1.25</td>
<td>0.310</td>
<td>17 6.73 1.26</td>
</tr>
<tr>
<td>Skull:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cbl., mm</td>
<td>8 8.43 0.09</td>
<td>0.433</td>
<td>11 8.45 0.14</td>
</tr>
<tr>
<td>MxtL., mm</td>
<td>8 3.61 0.04</td>
<td>0.025</td>
<td>11 3.42 0.03</td>
</tr>
<tr>
<td>Bcl., mm</td>
<td>8 3.68 0.06</td>
<td>0.193</td>
<td>11 3.84 0.26</td>
</tr>
<tr>
<td>PtL., mm</td>
<td>8 4.10 0.06</td>
<td>0.471</td>
<td>11 4.11 0.08</td>
</tr>
<tr>
<td>RtrW, mm</td>
<td>8 1.66 0.01</td>
<td>0.269</td>
<td>11 1.63 0.01</td>
</tr>
<tr>
<td>EorW, mm</td>
<td>8 5.03 0.11</td>
<td>0.111</td>
<td>10 4.82 0.14</td>
</tr>
<tr>
<td>IorW, mm</td>
<td>8 2.21 0.02</td>
<td>0.309</td>
<td>11 2.05 0.98</td>
</tr>
</tbody>
</table>
The male stone martens were deemed statistically significantly bulkier than the females in terms of the following: body mass (p=0.017), fur weight (p=0.017), tail length (p=0.062), girth (p=0.075), and body length (p=0.077). The body mass with fur of the male pine marten was larger than that of the female by 16%, the fur weight by 24.8%, the tail length by 8.6%, the girth by 6.6%, and the body length by 2.4. The ear length and hind leg length did not indicate reliable sexual dimorphism differences of the marten species.

The sexual dimorphism of both species of the subadult marten was studied based on the craniometric data (Table 2 and 3). The majority (12 out of 14) of different skull parameters revealed a reverse trend of comparing the body parameters, i.e. the skull of a female pine marten was slightly larger than that of a male. Several of the skull measurement data resulted in a statistically significant heftiness of the skulls of the pine martens compared to those of the males, i.e. the skull mean values of the female pine martens were higher than those of the males, respectively: PtL (10 %), MxtL (4.7 %), CbL (2.4 %), MnbL (3.5 %). No statistically significant sexual dimorphism of the pine martens was determined according to the other skull data.

In most cases, the mean data of the craniometric measurements of the stone martens (Table 2) showed a slightly larger skull of the female compared to the male one. However, only the differences based on BcbH – (p=0.016), FcL – (p=0.025), MxtL (p=0.046), MnbH – (p=0.034) can be deemed statistically credible. The mean data of other craniometric measurements were statistically unreliable.

The results of this study allow stating that the sexual dimorphism of the Lithuanian subadult pine martens and stone martens are mostly defined by the following morphometric parameters of the body: body weight and length, girth and tail length. The following data were determined to have statistically credible (p<0.1) differences: (PtL), (MxtL), (Cbl) and (MnbL) of the pine marten and (BcbH), (MxtL), and (MnbH) of the stone marten. The sexual dimorphism of both species of subadult martens was statistically reliably attested only by the length of maxillary tooth row (MxtL) out of all the craniometric data of skull measurement data. No other statistically significant common sexual dimorphism of both species of the subadult martens was determined according to the other body and skull measurement data.

According to the literature the sexual dimorphism of many species of the Mustelidae Family is most heavily expressed in terms of body mass (Moors, 1980). Presumable, this tendency is a consequence of natural sexual selection (Webster et al., 2004).

Conclusions

It was determined that the subadult males of both species of martens were heftier than the subadult females in terms of the morphometric data of their bodies; however, their sexual dimorphism was not manifested as strongly. The males of both species of martens were slightly bulkier than the female specimens and the statistically significant differences were determined in the body mass, girth, fur weight and tail length data (p<0.1).

Following 14 distinct measurements of the skulls of both species of subadult martens, it was defined that the sexual dimorphism of martens was only faintly indicated by the craniometric data. The following data were deemed to have statistically credible (p<0.1) differences: (PtL), (MxtL), (Cbl) and (MnbL) of the M. martes and (BcbH), (MxtL), and (MnbH) of the M. foina. The sexual dimorphism of both species of marten was statistically reliably attested only by the length of maxillary tooth row (MxtL) out of all the craniometric data of skull measurement data.

The specific nature of hunting martens and formulating the study samples ordain that the samples of the craniometric data are often smaller than the samples of the morphometric data. Therefore, the problem concerning the credibility of the statistical conclusions on the dimorphism of martens based on the craniometric data remains. To solve this problem, it is imperative to firstly improve the research database of both species of martens residing in Lithuania.

References


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Influence of Reparcelling of Land Plots on Landscape

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Aleksandras Stulginskius University

Abstract

The article presents analysis the motives of formation and reparcelling of land parcels projects and evaluation of their solutions’ affects to landscape.

The main intentions of the projects were estimated after research. First intention is to partition land parcels according to parts belonged to co-owners (to form separate parcels). The second is to divide land parcels in order to sell or grant to other person. The third intention is to specify borders between owned and neighbouring parcels.

Analysis of project solution ecological balance rate indicators shows a result that scarcely stable territory was in 8 parcels (Kes = 0.34 – 0.50), totally ecological unstable territory was in 13 parcels (Kes ≤ 0.33), moderately stable territory was only in 2 parcels It was noticed that in many cases there were small negative changes of ecological balance rate. It depends on dividing process of arable land and more ecologically stable territories.

Key words: ecological balance, land use rationality, reparcelling

Introduction

Land must be rationally planned in order to use it. By using properly planned land you must ensure to keep required production level of agriculture, soil protection, ecological stability of terrain, agricultural land use improvement.

Land use planning is a system of tools, used by Government to implement land property and its usage section politics: applying terrain planning tools to organize consumption of land fund, that is valid academically, rational and favorable for environment, and that does accounting of country’s land fund, forms land parcels, measures boundaries of administrative units, attaches land to agriculture activity territories and other sections of utilitarian environmental management (Taryvydienė, 2008).

Order of rational agricultural landholding depends on law, Government’s decrees and other decrees those regulates documents of terrain planning. They define principal specific purpose of land use of particular territorial segment, method and nature of the use of a land parcel and other conditions and regulations (Kavaliauskienė, 2008).

Rational agricultural land-holding is planned by land use planning and other projects. Various farm holding branches those require land use, are adjusted by these projects. Furthermore, there must be considered natural resources saving subject and other interests of society requirements.

Formation and reparcelling of land parcel projects is being prepared and implemented when it is needed to divide, partition, merge or amalgamate land parcels that are registered in Immovable Property Register. This common land use service is used by land owners who want to regulate land, which is recovered from agrarian reform or acquired by other means. According to Planning Department’s survey, formation and reparcelling of land parcels projects were arranged 1–1.5k times in rural area yearly (Aleknavičius P. and Liaskovskaja, 2009).

Inside projects of formation and reparcelling of land parcels, must be defined principal specific purpose of land use, method and nature of the use of a land parcel. It is regulated by Government’s decree and rules ratified by Department of the Environment and Department of the Agriculture ministers (Lietuvos..., 2004). Other Government’s decree is used when it is needed to identify or eliminate land easements (Žemės servitutų..., 2004).

Land parcels must be formed properly in order to use it rationally and to avoid deterioration of ecological, recreational conditions and possibilities to develop agricultural activity. While separating solid arable land, meadow and forest parcel, land parcels must be formed compactly, in a rectangular or similar form and suited rationally (Žemės sklypų..., 2004). But in the current law there is no requirement for the minimum size and the form of the agriculture parcel, for example: the width of the parcel (Aleknavičius P., 2012). Results of the research demonstrate that a key indicator in the human system (i.e. the parcel size and changes in the parcel size), which is driven by socioeconomic processes as well as policy, has direct implications for indicators in the natural system (Robinson, 2012). Land-use convenience, time and labor costs allocated to economic activities, good-neighborly relations highly depends on the use of land use boundary configuration (Sližienė, 2010).

The aim of this article is to analyze the motives of formation and reparcelling of land parcels projects, evaluate their solutions’ affects to landscape and rationality, compatibility of projected land use.

Methodology of research

In order to do research, there were analyzed 391 formation and reparcelling of land parcels projects, those were created from 2005 to 2012 in eastern Lithuania. During analysis were evaluate project solution affects to environment and landscape.

Ecological balance rate is counted according to the following formula:

\[ K_{ee} = \frac{\sum k_P \times P}{\sum P} \]  

(1)
where $K_{es}$ – ecological balance rate,

$k_e$ – Land type ecological balance rate,

$P$ – Land type estate (area).

Measured land ecological balance rate (Table 1).

<table>
<thead>
<tr>
<th>Land</th>
<th>Ecological balance rate $K_{es}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arable lands</td>
<td>0.14</td>
</tr>
<tr>
<td>Meadows</td>
<td>0.62</td>
</tr>
<tr>
<td>Pastures</td>
<td>0.68</td>
</tr>
<tr>
<td>Gardens</td>
<td>0.43</td>
</tr>
<tr>
<td>Forests</td>
<td>1.0</td>
</tr>
<tr>
<td>Flora of trees and bushes</td>
<td>0.4</td>
</tr>
<tr>
<td>Marshes</td>
<td>0.79</td>
</tr>
<tr>
<td>Water basins</td>
<td>0.79</td>
</tr>
<tr>
<td>Closed territories, roads</td>
<td>0.0</td>
</tr>
<tr>
<td>Impaired lands (quarries)</td>
<td>0.0</td>
</tr>
<tr>
<td>Other lands</td>
<td>0.68</td>
</tr>
</tbody>
</table>

When ecological balance rate ($K_{es}$) average value is 0.67 or more, territory is balanced ecologically, 0.51–0.66 – stable moderately, 0.34–0.50 – scarcely stable and less than 0.34 – unstable. To form a land parcel of arable land or sowed meadows, its length and width proportion must be 1:3 or less. Land parcel boundaries must be identified with natural contours or artificial objects. If there are not any natural or artificial objects, land parcel boundaries must be projected straight, to compose regular boundaries of arable land parcel.

There were used cartographical, logical and analytical thinking methods.

Results

While forming real estate object, partitioning or dividing it, newly formed real estate objects must meet these requirements:

1) Using method must not contradict with documents of terrain planning;
2) Principal specific purpose of land use and nature of the use of a farm holding must not contradict with documents of terrain planning;
3) These objects can function independently from each other, unless law defines otherwise;
4) Possibility to estimate and calculate each object’s value (Žemės sklypų..., 2004).

Land parcels can be formed to prepare not only land use planning projects, but also detailed plans those implement terms of land administration:

1) Land parcel with buildings on it can be divided or partitioned only in a way to be able to exploit the building in a single parcel. Several land parcels cannot be formed under one registered building.
2) Formative land parcel boundaries between corner points must compose a closed contour. Several land parcels those are divided by other real estate objects (roads, streets, railroads, unprivatized objects, etc.), must be formed as separate land parcels;
3) If there are not any possibilities to partition a land parcel into parts indicated by co-owners, formative parcel area must be rounded up, but the whole land parcel’s area must not be changed. In the case when area of land parcel is calculated in hectares, round up is 2 numbers after comma;
4) While modifying land parcel boundaries and size, forming new land parcels, it is a must to follow defined requirements of rational use of land, detail plans and land use planning project preparation.

There were analyzed 391 formation and reparcelling of land parcels projects, those were created from 2005 to 2012 and they are owned by 535 possessors. The most usual operation is parcel dividing - present parcels are divided into 2 or 3 land parcels (Table 2).
Table 2. Reasons of formation and re-parcelling of land parcels

<table>
<thead>
<tr>
<th>Year</th>
<th>Number of owners</th>
<th>Number of dividing projects</th>
<th>Reasons of land parcel dividing</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Between co-owners</td>
</tr>
<tr>
<td>2005</td>
<td>67</td>
<td>49</td>
<td>13</td>
</tr>
<tr>
<td>2006</td>
<td>70</td>
<td>54</td>
<td>17</td>
</tr>
<tr>
<td>2007</td>
<td>98</td>
<td>64</td>
<td>8</td>
</tr>
<tr>
<td>2008</td>
<td>88</td>
<td>64</td>
<td>12</td>
</tr>
<tr>
<td>2009</td>
<td>96</td>
<td>72</td>
<td>16</td>
</tr>
<tr>
<td>2010</td>
<td>36</td>
<td>28</td>
<td>5</td>
</tr>
<tr>
<td>2011</td>
<td>42</td>
<td>31</td>
<td>7</td>
</tr>
<tr>
<td>2012</td>
<td>38</td>
<td>29</td>
<td>7</td>
</tr>
<tr>
<td>Total:</td>
<td>535</td>
<td>391</td>
<td>85</td>
</tr>
</tbody>
</table>

The main reasons to prepare these projects:
1) To partition land parcels according to parts belonged to co-owners (to form separate parcels);
2) To divide land parcels in order to sell or grant to other person;
3) To specify borders between owned and neighbouring parcels.

While re-parcelling agricultural land, it is important that after re-parcelling there would be better conditions to use land according to its defined purpose. That is why instructions are the same as to form new land parcels, during reform. Furthermore, it must be estimated if private interests to divide land parcels do not contradict with purpose to make better conditions for land use (arable land cultivation or other agricultural activity).

Many parcels before dividing and re-parcelling projects were formed like trapeziums (37,12%). After dividing and re-parcelling projects, number of regular parcels increased considerably (Fig. 1).

Figure 1. Number of land parcels in aspect of its form after formation and re-parcelling projects

To sum up, it can be said that quality of parcels improved in aspect of configuration but there are still many irregular form parcels. There are various reasons why irregular form parcels occur after forming and re-parcelling projects. Usually this kind of parcels are formed beside lakes, every parcel owner on request want to have access to shore of a lake.

It is usual that residential or other constructional land parcels are formed from agricultural land which has polygonal or patch form (Ramanauskas and Dringelis, 2011).

Agricultural territory land use planning is secure when projected means meet requirements of landscape forming. In order to optimize landscape, it is a must to analyze its state – natural and semi-natural sprouting places and their functions; also it is needed to calculate ecological balance of particular territory (Sudonienė, 2003).

There were made calculations of ecological balance for some parcels on purpose to estimate partitioned land parcels’ affect to the landscape. Evaluated parcels were those, which were partitioned into three separate parcels and which parcels ecological balance before re-parcelling was unstable, scarcely stable or moderately stable. Project solution ecological balance rate indicators were analyzed. As a result, it was estimated that scarcely stable territory was in 8 parcels ($K_{ss} = 0.34 – 0.50$), totally ecological unstable territory was in 13 parcels ($K_{us} \leq 0.33$), moderately stable territory was only in 2 parcels (Table 3).
Table 3: Change of ecological balance rate

<table>
<thead>
<tr>
<th>Ecological balance rate before reparation</th>
<th>Ecological balance rate after reparation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 parcel</td>
</tr>
<tr>
<td>0.32</td>
<td>0.43</td>
</tr>
<tr>
<td>0.14</td>
<td>0.14</td>
</tr>
<tr>
<td>0.17</td>
<td>0.14</td>
</tr>
<tr>
<td>0.15</td>
<td>0.15</td>
</tr>
<tr>
<td>0.48</td>
<td>0.45</td>
</tr>
<tr>
<td>0.20</td>
<td>0.20</td>
</tr>
<tr>
<td>0.45</td>
<td>0.50</td>
</tr>
<tr>
<td>0.40</td>
<td>0.43</td>
</tr>
<tr>
<td>0.13</td>
<td>0.13</td>
</tr>
<tr>
<td>0.29</td>
<td>0.25</td>
</tr>
<tr>
<td>0.45</td>
<td>0.35</td>
</tr>
<tr>
<td>0.30</td>
<td>0.40</td>
</tr>
<tr>
<td>0.35</td>
<td>0.30</td>
</tr>
<tr>
<td>0.60</td>
<td>0.55</td>
</tr>
<tr>
<td>0.50</td>
<td>0.50</td>
</tr>
<tr>
<td>0.25</td>
<td>0.30</td>
</tr>
<tr>
<td>0.25</td>
<td>0.25</td>
</tr>
<tr>
<td>0.20</td>
<td>0.20</td>
</tr>
<tr>
<td>0.45</td>
<td>0.40</td>
</tr>
<tr>
<td>0.65</td>
<td>0.50</td>
</tr>
<tr>
<td>0.34</td>
<td>0.42</td>
</tr>
<tr>
<td>0.15</td>
<td>0.15</td>
</tr>
<tr>
<td>0.13</td>
<td>0.13</td>
</tr>
</tbody>
</table>

Summarizing estimated ecological balance rate indicators, it was noticed, that after reparation initial parcel into more parcels, in many cases this indicator does not change considerably, yet it increases. In separate occasions ecological balance decreases. It is determined by arable land partition from ecological stable territories. Therefore, while partitioning land parcels land separation should be mosaic or part of projected territory should be transformed into more ecologically stable to ensure natural variety.

Conclusions

Analysis of project solution ecological balance rate indicators shows a result that scarcely stable territory was in 8 parcels (Kes = 0.34 – 0.50), totally ecological unstable territory was in 13 parcels (Kes ≤ 0.33) and moderately stable territory was only in 2 parcels.

Many small changes of estimated ecological balance rate indicators were noticed after land parcel dividing. They depend on dividing process of arable land and more ecologically stable territories.

During the partitioning of land parcels, land separation should be mosaic or a part of projected territory should be transformed into more ecologically stable to ensure natural variety. In order to make projects of formation and reparation of a land parcel, it is important to evaluate both land use rationality and ecological stability.

References


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Land Resources Planning and Management

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Abstract

The main territory planning aims are as follows: to preserve, rationally use and recreate natural resources, nature and cultural heritage valuables, among them – and recreational resources, to coordinate interests between physical and juridical persons and their groups, society, municipalities and the state over the conditions of the land plot use and activity development in this territory. When defining particular territory planning aims it is necessary to take into account society demands, peculiarities of the landscape of the planned territory, geographical conditions, urban, architecture, technical, environmental, heritage protection, agricultural purpose land use and management requirements, land and other immovable property users’ and third persons’ rights, state security and defence demands. Unlimited extraction of limited resources can cause serious problems of environmental protection.

The licences for the extraction (location) of mineral resources are given without contest (except oil), i.e. they are given to those, who were among the first to fill applications. In such case, not only principles of competition are violated, but the state does not receive all possible benefit from its property as well. Therefore, it is supposed that the licences for the extraction of mineral resources should be given only according to the set order (auction).

Under current legislation, the environmental impact must be considered when mineral mining takes place in the land area of 25 ha and larger. Using underground resources (regardless of the size of the quarry) the natural environment is replaced, therefore it is necessary to assess the environmental impact in all cases.

Mine owners and land users exploiting mineral resources must keep to the requirements set by legal acts in order to preserve the fertile soil layer. In order to ensure the fertile layer of soil conservation and to improve the recultivation process the environmental education and knowledge of land owners and users on the use of mineral resources and environmental impact is necessary.

Introduction

Mineral resources occupy significant part in the national property of the state and should be properly recorded, protected, rationally used, their territories should be properly planned and society should be acquainted with the problems of the use of mineral resources. Only with the reliable information on the underground resources, on their use as well as on the processes and problems occurring in them it is possible to properly improve their territory planning.

The issues of resilience and vulnerability are likely to become more important in the framing of resource management questions in the future. They provide a bridge between the analysis of institutions and economies with the natural resources on which they ultimately depend. In policy terms these are also useful since both ecological stability and resilience are perceived as desirable social goals for many issues, from nature conservation through to climate change. It is argued by ecologists that resilience in natural systems provides the capacity to cope with surprises and large-scale changes – this is precisely what will allow innovation, coping with change and social learning in social institutions (Neil, 2000).

The main territory planning aims are as follows: to preserve, rationally use and recreate natural resources, nature and cultural heritage valuables, among them – and recreational resources, to coordinate interests between physical and juridical persons and their groups, society, municipalities and the state over the conditions of the land plot use and activity development in this territory. When defining particular territory planning aims it is necessary to take into account society demands, peculiarities of the landscape of the planned territory, geographical conditions, urban, architecture, technical, environmental, heritage protection, agricultural purpose land use and management requirements, land and other immovable property users’ and third persons’ rights, state security and defence demands. Unlimited extraction of limited resources can cause serious problems of environmental protection. Land areas affected by miningshould be recultivated after the completion of the exploitation of all or part of the deposit for mineralresources, i.e. by the deadlinesand methods predicted in useproject.

In the Law on the underground resources the use of the underground resources is defined as activity during which the data on the underground resources are received (Lietuvos, 1995). The types of the use of the underground resources are as follows: exploration of the underground resources; the use of the underground resources; the use of the cavities of the underground resources. The exploration of the underground resources is one of the types of the use of the underground resources. The licence for the exploration of the cavities (location, search) enables the possessor of this licence to ask for the repeated licence to use the located resources (using one’s own means), therefore, the majority of
enterprises ask for licences and in such way they want to ensure the bigger amount of the mineral resources’ territories for exploitation purposes.

The Lithuanian Geological Survey under the Ministry of Environment manages the Registry of the underground resources, disposes of the entire information on the mineral resources and renders it to all wishing physical and juridical persons according to the order set by laws. Besides, this geological survey summarizes data on mineral resources, compiles state maps of mineral resources at scales M 1:200 000 and M 1:50 000, carries out the analysis of the use of mineral resources.

The article aims to analyse land resources’ planning and usage problems.

The object of the investigation was the territory of the Republic of Lithuania, mineral resources.

Statistical analysis, questionnaire survey and comparison methods were used in the study.

Objectives: to analyze the mineral resources areas and emerging issues as well as legislation governing those processes; to discuss fertile layer of soil conservation and mineral deposits rehabilitation problems.

Results

Mineral resources’ use is an integral part and one of the key premises of development worldwide. With population growth and increase in society’s development needs, the requirements for minerals have grown and diversified. Across the World, on the annual basis, there are approximately 23 billion t of mineral resources that are exploited, out of which 18 billion t are of solid nature and 5 billion t are oil and gas. The structure of a solid mineral resources’ use reflects that the non-metallic ones account for the largest part (12.0 billion t per annum), followed by the coal exploitation (3.5 billion t per annum) and metallic mineral resources exploitation (2.5 billion t per annum). There are over 50,000 mines around the world in which approximately 200 types of mineral resources are in use (The use, 2011).

In Lithuania, solid mineral resources are classified according to three criteria: the geological survey, feasibility study, and the use of economic valuation. These criteria consist of a single three-dimensional resources survey and evaluation system. Resource economic value and usage possibilities mainly depend on the technological development, country's economic situation and developments in the market and are variables, and particularity of geological survey is determined by the results of geological investigation stages (Lietuvos, 1999).

In Lithuania, 17 types of mineral resources, among which 9 (limestone, dolomite, sand, gravel, clay, chalk marl, peat sapropel and oil) are exploited, are investigated at various levels at present. These mineral resources are used for the building materials industry and road building purposes. These mineral resources are the most important worldwide according to consumption amount (22 billion tones) and economical value (yields only to oil, gas and coal) (Gamtos, 2007).

By December 31, 2012, following “The Statute of Underground Register“ and “The regulations of Underground Register arrangement”, 2576 deposits of mineral resources and ground water had been included into the chapter of underground resources. During the year 2012, 21 new deposit of mineral resources and 22 deposits of underground water were included into the chapter of underground resources; 1079 boreholes were included into the chapter of boreholes and 295 objects of geological investigations were included into the chapter of geological investigations.

The area of the particularly located deposits of non-metal mineral resources makes up approx. 75 630 ha (of these – 56 930 ha of peat) or 1.2 per cent of whole Lithuanian territory. The area of preliminary located resources makes up approx. 116 840 ha (of these – 100 370 ha of peat) or 2 per cent of the whole Lithuanian territory.

According to the data received from the Lithuanian Geological Survey under the Ministry of Environment, at the end of 2002, 108 enterprises and 1 physical person had licences to explore the underground. In 2008, 75 licences (27 new and 48 repeated) were given for the usage purposes of the cavities and resources of the underground. 230 agreements on the usage of resources were made. The validity for 50 licences, of these 44 – for repeated ones, was eliminated(http://www.lgt.lt).

In 2011, following „The delivery procedure of permissions to use mineral resources (except hydrocarbons), resources of industrial and mineral groundwater and cavities of the underground“ (Leidimu, 2002) permissions to use mineral resources were granted to 60 enterprises, 144 contracts of the use of resources were concluded, and 49 permission were revoked (36 – in the case of granting a reissued permission;1 – in the case when a licence-holder was liquidated, 4 – in the case when the contract validity expired, 6 – at the request of the licence-holder, 1 – in the case when a licence-holder had regularly committed breaches of the terms of exploitation of resources. By December 31, 2011, 279 enterprises and 1 group of legal persons acting under the contract of joint activity had permissions to use resources of solid minerals and mineral water (http://www.lgt.lt).

The number of enterprises, which had licences to use solid mineral resources during 1999-2013, is presented in Fig. 1.
Figure 1. The number of enterprises having licences to use solid mineral resources

As one can see from the figure, the number of enterprises having licences to use solid mineral resources, increased. In 2013, 234 enterprises had the licences for the engagement in the extraction of solid mineral resources, whereas in 1999, only 169 enterprises had such licences. It can be related with the increasing amounts of the building works of dwelling houses and roads during the latter years. The majority of them are gravel and sand mining enterprises. The second (according numerosity) go enterprises engaged in peat extraction. These enterprises are small according to the number of working people in them, i.e. less than 50 people.

Having made analyzes the authors of the article identified several key issues, such as:

1. The problem – it is allowed to use natural resources without auction.

Following the instructions (approved by the Government of the Republic of Lithuania (resolution №198, passed on February 11, 2002)) on the giving of the Licences to use mineral resources (except carbohydrates), industrial groundwater and mineral water resources and the cavities of the underground, the Lithuanian Geological Survey under the Ministry of Environment gives licences and makes agreements with juridical persons or the groups of these persons (acting according to the joint activity agreements). The information over the giving of licences, the suspension of validity, the elimination of validity suspension and the elimination of validity is published (by the Lithuanian Geological Survey) in the appendix “Informaciniaipranešimai” of the newspaper “Valstybėsžinios”. Therefore, all wishing persons are able to get to know with the publicly declared information (Leidimų, 2002).

At present, the licences for the extraction (location) of mineral resources are given without contest (except oil), i.e. they are given to those, who were among the first to fill applications. In such case, not only principles of competition are violated, but the state does not receive all possible benefit from its property as well. Therefore, it is supposed that the licences for the extraction of mineral resources should be given only according to the set order (auction).

2. The problem – conservation of the fertile layer of soil.

Soil resources can be used only in the land plot (formed according to the order set by the Territory planning law and Land law) used for other objective purpose on ownership or other legal basis. Soil resources can be used only according to the approved usage project. The questions on the removing and preservation of vegetation layer should be presented and analysed in the chapter of the mining part of the explanatory text of the usage project.

It should be noted that landowners and other users must follow the requirements set by legal acts (when exploiting mineral resources) in order to preserve fertile soil layer and recultivate the damaged land. Landowners and other users must implement measures defined by legal acts over the protection of forests, lands and water reservoirs from pollution, over the soil protection from erosion and impoverishment. The area of the damaged land during mining works covers 13.6 thousand ha. Damaged peat bogs cover 78 per cent of this area. Damaged lands (during mining works) are recultivated after the ending of the exploitation of mineral resources.

As it is declared in the Constitution of the Republic of Lithuania (Article 47) the underground belongs by the right of exclusive ownership to the Republic of Lithuania. The restored State of Lithuania is obligated to take care of the protection of the natural environment and to supervise sustainable use of natural resources, their preservation and control.

According to Resolution № 343 (chapter LII, item 208) of May 12, 1992 of the Government of the Republic of Lithuania on „Special use conditions of land and forest“, approved by the regulation of soil protection, it is important to preserve fertile soil layer when carrying out mining works (Lietuvos, 1992).

The user of soil resources can be called to account for the violation of the requirements predicted in the legal acts on the use of soil resources. In Article 52 of the Code on”Violation of administrative laws“ the responsibility for the preservation of the fertile soil layer is predicted.

Following Order № 166 of November 15, 1996 on “Methodology of the recultivation of the damaged lands after the extraction of mineral resources”, approved by the Ministry of Environmental Protection of the Republic of Lithuania, it was defined that the recultivation of the quarries of mineral resources and peat bogs is carried out according to the usage-recultivation projects. In this project the following items are predicted: direction of recultivation,
work fulfilment order, the place of fertile soil layer as well as partial recultivation and measures for the protection of the mineral resource revenues when exploitation of deposits is temporary or entirely stopped.

Following Order № D1-444 (Item 3) of October 3, 2006 of the schedule on “Order of the control of the use of the mineral resources exploited by open workings” (Atvirais, 2006), approved by the minister of the environment of the Republic of Lithuania, departments of the regions of the Ministry of Environment and the Lithuanian Geological Survey under the Ministry of Environment ensure the rational use of the mineral resources exploited by open workings controlling the use, protection and record of these resources according to competence, the impact of the extraction of mineral resources upon the environment, conservation of the fertile soil layer, recultivation of damaged lands as well as the conditions set in the project of the use of resources (approved by the Lithuanian Geological Survey) and in the agreement on the use of resources made between the user of the deposit and the Lithuanian Geological Survey. Consequently, the above-mentioned acts define not only the order for the use of mineral resources, but the preservation of the fertile soil layer, recultivation of quarries as well.

There is currently no information compiled about how much of fertile soil layer in each quarry is dug out and how it is stored. According to the authors of the article, it hasn’t been discussed enough in the legislation how the accounting and control of the fertile layer of soil conservation and soil storage should be carried out, therefore, it is necessary to be regulated.

3. The problem – quarry recultivation.

Land recultivation - it is a whole of technical, engineering, construction and biological works, aiming to make the damaged land suitable for human economic activity(Metodiniai, 1999).

According to Resolution № X-1186 of June 14, 2007, the Seimas of the Republic of Lithuania approved the program on „Natural resources preservation and protection“. The above-mentioned program also notes that the lands damaged during mining works are recultivated after the ending of the exploitation of mineral resources (Gamtos, 2007).

Any kind of extraction of mineral resources replaces the established balance of the natural environment, so after mining the damaged territories should be neutralized as far as possible. The depth of gravel, sand, clay, peat and dolomite quarries is usually 6-12 m, the depth of limestone and opoca quarries normally reaches 15-30 m. According to V. E. Gasiūniénė (Gasiūniénė, 2009), in accordance with the principles of sustainable development, the sourcing with mineral extraction should take place in the exploration of new deposits of mineral resources, rational use of known supplies, searching for technological innovations in mining and processing of raw materials, changing consumer habits and improving the legal framework in the field of deposits of mineral resources.

The last inventory of the land damaged by quarries and peat bogs was conducted in 1998. According to recent data quarries damaged about 9.829 ha and peatlands – 17.021 ha of the country’s area (land areas damaged by illegal mining were not included into this area). The inventory data on the damaged areas carried out in 1998 is inaccurate, information about the quarries is not stored and there is no analysis about the land damaged by quarries and peat bogs as well as their damages’ origin reasons. In the absence of such information, it is impossible to effectively manage and control the damaged area reduction and landscape restoration process(Valstybinio, 2012).

The data on the deposits of underground resources, the cavities of the underground resources, mining holes, and underground explorations are accumulated in the Register of underground resources. The register of underground resources is a constituent of the state geological information system. The aim of the register – to record deposits of underground resources, the cavities of the underground resources, mining holes and underground explorations, to gather, accumulate, systematize, preserve, process, use and present the data and documents of the register to physical and juridical persons and their groups acting according to the joint activity agreements.

With the wider use of the possibilities of modern technologies when preparing territory planning documents of mineral resources and discussing with public over them, coordinating between institutions as well as when publicizing the already prepared projects, errors would be avoided and the time of procedures would be shortened.

Inadequate supervision of quarry users and the delayed recultivation of these quarries conditioned that damaged lands became illegal dumps. As a result their clean-up costs have increased by about 15 times or 35 million Lt. Lack of an effective control system does not prevent illegal mining. Part of municipalities did not carry out landscaping and security functions, predicted in the Local Government Act. Therefore, not all quarries, predicted in the exhausted quarries usage (according to its intended purpose) plan, were recultivated. The Special Climate Change Programme and the Environmental Support Program funds may be used for recultivation of quarries, but this option is not used(Valstybinio, 2012).

According to the opinion of the Lithuanian Quarry Association, the problem concerning the recultivation of damaged lands could be partially solved when making delays in payments for account of profit in proportion to the exhausted area of the deposit. Such delays should be accumulated in a special account of the enterprise, where means should not be taxed by profit tax and cumulative means could not be used for other purposes, except for recultivation. In such case means would not disappear even in the case of bankruptcy.

Not recultivated quarries often become illegal dumps which become the source of the air, soil, shallow groundwater and groundwater pollution. At present, there is no system ensuring the full use of quarry recultivation, and nobody has discussed the way the recultivated quarries are accepted, therefore it affects both the state budget and the environment. The authors of the article believe that a detailed and accurate information about the damaged land in our country should be collected and analyzed continuously and this should be done by one institution, which should coordinate the land recultivation process according to the data available.

4. The problem – dissatisfaction of the population living near the operating quarries.
Provision of real participation and dialogue with communities affected by the mining activity, as well as with other stakeholders involved in social and environmental aspects of the mining activity (The use, 2011).

The analysis has shown that quite often quarries are exploited near residential areas or cities (Fig. 2).

Figure 2. Quarry location site in respect of residential areas

The authors of the article interviewed 32 people from Akmene, Anyksciai and Kaunas districts living up to 3 km from the operating quarries. The survey showed that 87 per cent of respondents are aware what kind of mineral deposits are adjacent to their residence and what kind of minerals are mined in it, but only 12 per cent knew how exactly quarry will be recultivated after the end of its exploitation. Residents living near the used quarries complained that the company's representatives planning to dig or digging minerals are reluctant to consult with local residents as well as to provide information on quarry exploitation activities (what is dug, how long it will last, in which way it will be recultivated, etc.). Most frequently mentioned problems of mineral excavation are as follows: noise, vibration, dust, road destruction by transport transporting minerals and lack of information. According to the survey results, the authors of the article consider that the dissatisfaction of population with the existing quarries is increasing for the absence of information or lack of it.

According to the Law on Planned Economic Activity Environmental Impact Assessment of the Republic of Lithuania the planned economic activity environmental impact must be assessed when mineral mining takes place in the land area of 25 ha and larger. Natural environment using underground resources is replaced regardless of the size of the quarry, so the authors consider that environmental impact assessment and the preparation of the impact assessment report is necessary in all cases.

Conclusions

The licences for the extraction (location) of mineral resources are given without contest (except oil), i.e. they are given to those, who were among the first to fill applications. In such case, not only principles of competition are violated, but the state does not receive all possible benefit from its property as well. Therefore, it is supposed that the licences for the extraction of mineral resources should be given only according to the set order (auction).

Landowners and land users exploiting mineral resources must keep to the requirements set by legal acts in order to preserve the fertile soil layer. In order to ensure the fertile layer of soil conservation and to improve the recultivation process the environmental education and knowledge of land owners and users on the use of mineral resources and environmental impact is necessary.

There is currently no information compiled concerning how much of fertile soil layer in each quarry is being dug out and how it is being stored. There hasn’t been sufficiently discussed how the accounting and control of the fertile layer of soil conservation and soil storage should be carried out, therefore it is necessary to be regulated.

With the wider use of the possibilities of modern technologies when preparing territory planning documents of mineral resources and discussing with public over them, coordinating between institutions as well as when publicizing the already prepared projects, errors would be avoided and the time of procedures would be shortened.

At present, there is no system ensuring the recultivation of all exhausted quarries, and there was not exactly discussed the way in which the recultivated quarries are accepted, therefore it affects both the state budget and the environment. Comprehensive and accurate information about our country’s damaged land should be collected and analyzed continuously and this should be carried out by one institution, according to the data available to coordinate the land recultivation process.

Under current legislation, the environmental impact must be considered when mineral mining takes place in the land area of 25 ha and larger. Using underground resources (regardless of the size of the quarry) the natural environment is replaced, therefore it is necessary to assess the environmental impact in all cases.
References


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Measure of Real Estate Objects by Photogrammetric and Laser Scanning Methods

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Abstract

Geometrical elements of the facades of buildings and structures mostly are measured, when there appears the need for the real estate objects to be preserved, reconstructed, renovated and inventory has to be compiled. The following methods of measurements regarding buildings are widely accepted and recommended, namely the terrestrial techniques for surveying. In the article describes two methods are most widely applied at present in the world of terrestrial – close-range photogrammetric and laser scanning. The theoretical studies as well as practical samples of measurements are described. The objective of the article is to present the advantages as well as the observed limitations and disadvantages of these two terrestrial methods.

Key words: cultural heritage, inventory, geometrical elements of the facades of the buildings and structures, laser scanning.

Introduction

For real estate object registration purposes geometric information about existing buildings or the ones under construction in 2D plans or three dimensional (3D) CAD models is necessary, for control, conservation or reconstruction. If the data are still available from the construction process, they may have insufficient actuality. In a modern environment the 3D CAD data are preferred, showing the actual state of the building. These data may be acquired by a manual measurement using geodetic survey instruments, by theodolites or tachometers, or by close-range photogrammetry using digital images or by new technology – laser scanning. Photogrammetry and laser scanning methods are described in a greater detail in the article.

The terrestrial surveying method – close-range photogrammetry often has to be used for inventory, fixation and control the real estate and heritage objects. The output of close-range photogrammetry is a digital object or terrain images in the plane or three-dimensional space. A precise data of the real estate object is photographed by a professional – a digital photo-camera with the calibrated lens optical system (evaluation of optical lens distortion parameters). The camera calibration is performed in a laboratory or with special calibration software using special test field of camera calibration. The images are processing by special photogrammetry softwares. After that we have a geometry model of object and to reveal the value of the real estate objects, there has to be carried out their physical and project research and if needed the constructional works are executed. Based on the data of these investigations, there is determined the significance of the objects of the real estate or the valuable characteristics of the areas or locations of their presence are depicted. The Register List of Real Estate objects is arranged, administered, introduced and renovated by the prescribed laws and orders of the State Registers, Real Estate Cultural Heritage, Mobile Cultural Heritage Preservation (the provisions of the laws are harmonized with the legal acts of the European Union) and the order approved legal acts (Law on Preservation…., 2008, Law on State…., 2004, Low on Movable…., 2009).

The laser scanning method has to be used to measure geometry elements of simple, uncomplicated registration to Real Estate objects. Object measurement and registration procedure governed by the Real Property Cadastre and Register Law (Law on Movable…., 2009).

1. Close-range photogrammetric method applied in deriving geometrical data of a building facade

Among the advantages of the close-range photogrammetric method is the possibility to receive a spatial, detailed model of an object, the elements of the facade of the building are obtained in the three-dimensional system of coordinates ($X$, $Y$, $Z$ coordinates). To receive a spatial model there have two photographs to overlap each other as well as some reference points, the coordinates of which are determined by using a geodetic method (by a theodolite or a tachometer). A digital camera is used to take the photo of an object from two or one reference points. (Fig. 1) (Albert et al, 2000). The photos from one point are made when buildings or their elements are flat. The distance between two reference points comprises $B$ base of photographing.

![Figure 1. The nature of taking building facade photos from two reference points (a), from one reference point (b)](image-url)
At present an accurate and a detailed image of the building facade is mostly received by close-range photogrammetric method, when with the assistance of the software there could be compiled digital ortho-photographic maps of buildings in accordance with digital photos, which are digitalized and afterwards there are obtained the required geometric elements of the building. Here are the following programs to be applied, namely ORIENT (produced in Austria), PUMATEC (in Norway), OrthoVista (in Germany), Alexis and PhotoMod (in Russia) and some others.

In stereo-photogrammetric measurements, the spatial coordinates of points are determined following the photogrammetric formula (Serdiukov, 1970):

\[
Y = B \frac{f}{p}; \quad X = B \frac{x}{p}; \quad Z = B \frac{z}{p},
\]

where \( B \) – is the base of taking photos; \( f \) – is the distance of the camera lens focal; \( p = x_k - x_d \) – is the vertical parallax residual in the overlapping of the measured point; \( x, z \) – are the coordinates of the measured point on the photo, situated on the left.

When carrying out the measurements on one photo, the point coordinates are equal (Serdiukov, 1970) to:

\[
X = Y \frac{x}{f} = xM, \quad Z = Y \frac{z}{f} = zM,
\]

where \( \frac{1}{M} = \frac{f}{Y} \) – is the scale of the photo.

When the axis of \( Y \) coordinate coincides with the optical axis of the camera, the coherence between the photo and the coordinates of the object is expressed by these equations (Serdiukov, 1970):

\[
Y = B \frac{f}{p} \left( \cos \alpha + \frac{x_d}{f} \sin \alpha \right),
\]

\[
X = B \frac{x_k}{p} \left( \cos \alpha + \frac{x_d}{f} \sin \alpha \right),
\]

\[
Z = B \frac{z_k}{p} \left( \cos \alpha + \frac{x_d}{f} \sin \alpha \right),
\]

where \( \alpha \) – is the disposition of the optical axis of the camera (Fig. 2).

The transformation of the coordinates of points from photogrammetric system into the geodetic system of coordinates could be calculated in the following way:

\[
Y_g = Y_{nk} + Y \sin A_0 + X \cos A_0,
\]

\[
X_g = X_{nk} + Y \cos A_0 - X \sin A_0,
\]

\[
Z_g = Z_{nk} + Z_f + (k + r),
\]

where \( X_g, Y_g, Z_g \) – are the geodetic coordinates of the determined point; \( X_{nk}, Y_{nk}, Z_{nk} \) – are the geodetic coordinates of the projections of the left centre; \( A_0 \) – is the directional angle of axis \( Y \) in the photogrammetric system of coordinates; \( (k + r) \) – are the amendments made due to the curvature of the ground surface and refraction.

The whole investigated object could be covered by digital images when applying software, spatial triangulation could be carried out as well as the works of digitalization. This digital method provides stereoscopic measurements and allows obtaining a required accuracy of the points of the coordinates of the objects. Spatial triangulation reduces by maximum the number of over- ground bearing points and at the same time the scope of field works (Luhmann et al, 2006).

Digital photo processing is concerned with acquiring, transmitting, processing and representing images (Schenk, 2005). The principal procedure in close-range photogrammetry is shown in figure 4 (Luhmann at al, 2006):
Figure 4. Procedure of digital images processing

Nowadays we have digital modular systems which providing full photogrammetric production line from the aerial triangulation to the output of digital terrain models, digital maps and orthomosaics.

The experimental work was done by *PhotoMod* system. *PhotoMod* system is produced by Racurs Co. (Moscow, Russia) and has been dynamically developed since the version 1.1 in 1994. *PhotoMod*’s growing user base includes organizations throughout more than 45 countries worldwide. The main fields of application include: photogrammetric production, cadastral mapping, cartography and remote sensing, academic photogrammetry, mining, architecture and construction (Available from internet: http://www.racurs.ru).

Measure of real estate object by photogrammetry method

The analyses color digital images of the central part of house facade in Vilnius were taken by the *Canon EOS 1D Mark II* digital photo-camera (Fig. 5). This particular camera was calibrated (its optics distortions determined and evaluated) using *Tcc* software at the Institute of Photogrammetry of Vilnius Gediminas Technical University in 2009 (Sužiedelytė-Visockienė, Bručas, 2009). Focal length of the camera is 20.16 mm, the matrix pixel size $\text{pxl}=6.4 \, \mu m$.

Figure 5. Two overlapping images of house facade

Digital *PhotoMod* photogrammetric system consists of such modules (Kiseleva, 2002):

- *PhotoMod Montage Desktop*, used for creating the projects and connecting it to other modules;
- *PhotoMod AT* – measurement of points and creation of the geometric model;
- *PhotoMod Solve* – calculating of triangulation;
- *PhotoMod Stereo Draw* – stereo digitalization;
- *PhotoMod DTM* – creation of digital terrain model;
- *PhotoMod Mosaic* – generation of orthophotomap.

The geometric models were created by the *PhotoMod AT* module using the same control and tie points in the images (Fig. 6.).

Figure 6. The geometric model of house
After measuring control and tie points on two overlapping images, relative orientation parameters of images pairs are calculated and then recomputed more exactly while points being added. In the measuring points window shows the values of vertical parallax residual. Measurement units are pixels or millimeters depending on camera units. Status window shows RMS and Max (maximum) values of vertical parallax residuals. The results of precision rate of created geometric model – measurement precision are shown in Table 1.

Table 1. Precision rate of geometric model

<table>
<thead>
<tr>
<th>Deviation</th>
<th>Result, mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max. error of point parallax *</td>
<td>8</td>
</tr>
<tr>
<td>RMS** of point measurement</td>
<td>3</td>
</tr>
</tbody>
</table>

* transversal discrepancies of the same points in images.  
** RMS – root mean square error.

Mean vertical parallax value should not be greater than half of matrix pixel size for digital camera. In the example, if the scanning pixel size is \( p_{\text{pixel}} = 6.4 \, \mu\text{m} \), the mean value should not be more than \( 3.2 \, \mu\text{m} \). In our case Max are \( 8 \, \mu\text{m} \) and RMS – 3 \( \mu\text{m} \) (Table 1). These errors are estimating the quality of photogrammetric measurement.

The PhotoMod Solve module is used to adjust strips and blocks of images – the calculation of photo triangulation. After this stage we have control and tie points with geodetic coordinate in the geodetic coordinate system. The coordinates of control points were known from the geodetic measurement. Differences in coordinates of the processed points are in Table 2.

Table 2. Coordinate deviations of photo triangulation points

<table>
<thead>
<tr>
<th>Measure points</th>
<th>Coordinate deviation, m</th>
</tr>
</thead>
<tbody>
<tr>
<td>No.</td>
<td>( E_x )</td>
</tr>
<tr>
<td>100</td>
<td>-0.005</td>
</tr>
<tr>
<td>101</td>
<td>-0.020</td>
</tr>
<tr>
<td>102</td>
<td>-0.003</td>
</tr>
<tr>
<td>103</td>
<td>0.001</td>
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<tr>
<td>104</td>
<td>0.006</td>
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<td>105</td>
<td>0.004</td>
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<td>0.000</td>
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<tr>
<td>708</td>
<td>-0.004</td>
</tr>
<tr>
<td>709</td>
<td>-0.001</td>
</tr>
<tr>
<td>710</td>
<td>0.000</td>
</tr>
<tr>
<td>96</td>
<td>-0.004</td>
</tr>
<tr>
<td>97</td>
<td>0.000</td>
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<tr>
<td>98</td>
<td>0.003</td>
</tr>
<tr>
<td>99</td>
<td>-0.002</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Rate of precision, m</th>
<th>( E_x )</th>
<th>( E_y )</th>
<th>( E_z )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
<td>0.004</td>
<td>0.006</td>
<td>0.005</td>
</tr>
<tr>
<td>Max. error</td>
<td>0.020</td>
<td>0.012</td>
<td>0.014</td>
</tr>
<tr>
<td>RMS</td>
<td>0.007</td>
<td>0.007</td>
<td>0.006</td>
</tr>
</tbody>
</table>

In the table 2: \( E_{xy} \) – the \( x \) and \( y \) coordinates differences between the photo triangulation and geodetically measured points; \( E_z \) – the \( z \) coordinate differences between the photo triangulation and geodetically measured points; RMS – is the Root Mean Square of the measurement points.

The results presented in tables 1, 2 exhibit hight precision of photogrammetric measurements and adjustment of the images.

Using the PhotoMod Stereo Draw module are extracting data from images. Digitalization of objects could be done by stereo modes or mono mode (Racurs, 2009). Objects digitalization by stereo mode is performing by using...
anaglyphic or shutter glasses. Mono mode – all created vectors should be checked manually in images to avoid possible correlation errors. In the experimental object planimetric features are compiled in a stereo mode in which the photogrammetric operator digitizes (in real-world coordinates) points, lines, or polygons representing features of interest – textures of facade. Result is shown in figure 7.

![Texture of building facade](image)

Figure 7. Texture of building facade

The resulting data files can be imported directly into ArcMap for GIS use or into AutoCAD for engineering design. (Fig. 8).

![2D drawing of the house facade using photogrammetric data](image)

Figure 8. 2D drawing of the house facade using photogrammetric data

This result indicates a data about size of windows, wall, and height on the façade (Fig. 8). The data could be stored in the Real Estate of Lithuania. This house was ready for renovation.

**Measure of building by Laser scanning method**

In order to accumulate the inventory archives of the architectural heritage objects in European countries, there are used a laser scanning method for buildings (Albertz, Wiedemann, 2002; Vosselman, Maas, 2010; George et al, 2009).

One of the over-ground laser methods for 3D devises (*RIEGL LMS Z420i*) is submitted in Fig. 9 (http://www.rieegl.com3).
The principle of a laser scanner. The system of laser scanning is comprised of a laser scanner and a portable computer with a special software, with the assistance of which there is automatically received in a particular location, the ‘cloud’ in a three dimensional system of coordinates. By applying the fastest laser measurement systems it is possible to measure even 11000 points per second. The accuracy of the measurements is up to 10 mm (it depends on the distance).

During the process of taking photos or scanning it is possible to see only one side of a building. In order to have the total view of an object it is required to execute scanning from all sides (Fig. 10).

After joining all the points of the ‘cloud’ into the continuous geometric space there is received the whole and total 3D model of the building.

A standard Windows notebook and the bundled software package RiSCAN PRO enable the user to instantly acquire high-quality 3D data in the field as well as to provide a variety of registration, post processing and export functions. The software was prepared for the optimal, functioning processing of the obtained data as well as the generation of 3D model.

As a practical sample there has been selected not an object of cultural heritage, but 3D model of the first floor of Vilnius Gediminas Technical University in the under construction building, however the principal of the execution of the work has remained the same. The scanning of the building has been carried out by RIEGL LMS Z420i scanner. To operate the scanner during the scanning process and to process the obtained data there has been applied RiSCAN PRO software. This software has been developed to receive the data during the measurement process and it has been prescribed for data processing as well as storage. The derived result of scanning could be oriented in any selected system of coordinates. The derived results are exported into the required data files (e.g. could be applied for compiling a control photo of the target position).

The first position of scanning is the external side of the building (Fig. 11). During the working process, the greatest attention has been paid to the scanning of columns. When selecting the other position of scanning there has to be observed the former position as well as the common reflectors and their positions.

The building has been scanned from eight positions of scanning. The data are processed by RiSCAN PRO software, when for each separate position there is provided a different but not repeated colour. Thus allows observing from what scanning position an object or part of it has been scanned (Fig. 12).
When processing the data acquired from a huge number of points, they are passed through a filter (or clipped) and only the requisite points, necessary for the continuation of the work (point cloud) are left.

Software RiSCAN PRO is used in cases when from the whole view there have to be clipped the required elements of the building. Under the software influence sphere there is determined the required to be clipped territory, the process is repeated several times until the required result is derived (Fig. 13).

The accuracy of the columns interposition is determined by the precision of the oriented positions of scanning in between. When processing the data of the scanning motion (RiSCAN PRO), there have been determined that the data of the motion have been processed and attached to the bearing points with a Root Mean Square (RMS) error of 3.3 mm (Fig. 14).

With the assistance of software operations, it is possible to determine the geometric data of the building (height, width, length etc.). The data serve the inventory, inspection of the constructed structures and for architectural purposes. It is possible to carry out the correction of the data in case the realistic geometric measurements of a building have been provided.

**Accuracy at photogrammetric and laser scanning of real estate object**

Terrestrial surveys method – photogrammetry technical precision depends from:
- digital cameras, equipped with high resolution frame sensors;
- image processing techniques and softwares;
- precision of control points (geodetic methods);
- precision measurement in the images.

Also laser scanner technical precision depends from:
- scanning speed, sampling rate of laser measurement system field of view (camera view, profiling, imaging);
- spatial resolution, i.e. number of points scanned in field of view;
- accuracies of range measurement system and deflection system and overall for the systems;
- combination with other devices, mounted on the laser scanner (e.g. photo camera, GPS).

Both methods quality is determined from images or scanning point measurement accuracy. Results are shown in table 3.

<table>
<thead>
<tr>
<th>Methods</th>
<th>Point measurement, µm</th>
<th>RMS, µm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Close-range photogrammetry</td>
<td>± 2</td>
<td>± 1-5</td>
</tr>
<tr>
<td>Laser scanning</td>
<td>± 10</td>
<td>± 5</td>
</tr>
</tbody>
</table>
The precision is shown that photogrammetry and laser scanning methods have the same point measurement precision. In this case it is possible to make combination these two methods. Laser scanning method does not include enough information for an advanced understanding of the object. Recommend use combination of optical imagery (photogrammetry) and all properties of laser scanning data.

Conclusions

Close-range photogrammetry and laser scanning methods were presented in the paper as an option for measurements of buildings. Measurements and inventory of architecture heritage objects are usually based on the close-range photogrammetry, whereas the laser scanning methods usually fail to detect small elements of complex facades. The photogrammetric measurements on the images are also invaluable during the processes of building reconstruction. Our tests revealed the accuracy of building elements measured using close-range photogrammetry to be very high, i.e. the RMS errors of planar coordinates were inside 7 mm and the height – inside 6 mm. Laser scanning approach was discussed as having several advantages – e.g. the laser scanning works could be executed irrespective of the season, they could be easily automated. The accuracy of the details of test objects scanned in terms of RMS of all coordinates was found to be inside 10 mm. However, the laser scanning methods involved rather complex procedure of precise vector surface compilation using the point cloud data. Nevertheless, both solutions for digital coding of geometric elements of buildings were found to be meeting the requirements for Real Estate registration requirement.

References

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Analysis of Technical State Changes of Spillway Concrete Gravity Dams in Municipalities of Marijampolė and Kėdainiai District

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Aleksandras Stulginskis University, Lithuania

Abstract

The spillway dams are built when the pass of large floodwater and ice is necessary. These spillways can be: a) with gates b) without gates. Most of these dams have been used for more than 30 years, and due to various reasons (natural aging of materials, loading and various impacts: the mechanical, physical, chemical, specific) the properties of structures are changing and because of that the technical state of spillway decreases. The research of the technical state of concrete spillways is not sufficient. The aim of research was to investigate and to evaluate technical state of spillways in Kėdainiai district and Marijampolė municipalities, also to compare the results with those of previous investigations. The following structure diagnostic methods were used for investigations of technical state: laboratory works, visual method, non-destructive method for the estimation of concrete strength; the technical state was evaluated using methodology described in Standard STR 1.12.03:2006. Comparing the results of investigations performed in 2005 - 2012 with the results obtained in previous studies (1999-2005) it was found out, that the technical state: a) is stable in Kėdainiai distr. municipality (Kruostas) and Marijampolė municipality (Marijampolė II and Antanavas) spillways; b) is improved (due to its reconstruction) – in Marijampolės municipality (Marijampolė I); c) has worsened in deteriorated spillways of Kėdainiai distr. municipality (Akademija – Dotnuva and Juodkiškiai) and Marijampolė municipality (Kazlai and Netičkampis).

Keywords: concrete spillways, deterioration, technical state.

Introduction

In order to spill the floodwater and ice from the reservoir, spillways of various types are built. They are classified according to their purpose, usage time etc. These classifications are given in the works of Lithuanian (Damulevičius et al, 2009; Ruplys, 1988) or foreign (Rasskažov et al, 2008; Novak et al, 2001; Hydraulic of dams and river structures, 2004) authors.

In the world, arch, gravity or buttress dams are designed and built (Rasskažov et al, 2008; Ruplys, 1988). They are widespread in the territories, where the soil is strong and rocky, where torrential rivers can be submerged and a high acting head can be created. Most of them can be found in Norway, USA and Russia. These dams are designed in accordance with the requirements of Standards (EM 1110-2-1603; CHütP 33-01-2003..., 2004). The previously mentioned types of dams are not spread in Lithuania, because of the absence of strong rocky soils, i.e. solid ground, which would be suitable for the construction of these dams, there is also a lack of large and torrential rivers, which could be submerged, making this way a high pressure. In Lithuania, spillway dams are designed, built and maintained in accordance with the requirements of Standards STR 2.02.06:2004; STR 2.05.14:2005; STR 2.05.15:2004; STR 2.05.18:2005; STR 1.12.03:2006; Hydraulic Structures Design, 2001; Hydraulic engineering, 2000.

All the hydraulic structures (HS), including spillway concrete gravity dams (SCGD), are used in complicated conditions of the environmental impact: they are affected by natural (atmosphere, water, ice and slush, high or low temperature, atmospheric precipitation, wind and storm, solar radiation) and various technological factors. Due to these factors, various deteriorations appear in the HS constructions; they reduce the bearing capacity of constructions (or spillway) to water pressure, the technical state of SCGD constructions decreases.

The exclusive characteristic of SCGD is a constant contact with water environment, which can affect its spillway, foundation and its immediate environment mechanically, physically, chemically or biologically. It is the mechanical effect of water, which is the most significant in the calculation of SCGD effects and loads (STR 2.02.06:2004). The mechanical impact of water can be static (hydrostatic, geofiltrational; the pressure of ice cover) and dynamic (the effects of stormy currents and waves, hits of ice floss, hydraulic thrusts, vibration, seepage flow impacts to soils). Mechanical effect is the reason for the rapid progress of the deteriorations in SCGD concrete constructions and deterioration.

In Lithuania, dams’ observations and, to a certain extent, researches have been carried out since the dams were built, nevertheless the greatest attention has been focused on the field observations of earthen dams (Damulevičius et al, 2001; Damulevičius, Vyčius, 2008). The researches of the SCGD reinforced concrete constructions state were carried out in 1999-2005 by the specialists of the Department of Building Constructions in Aleksandras Stulginskis University (ASU); the results were generalized in the report (Natūrinių ir anketinių duomenų... , 2009) and in the paper (Damulevičius et al., 2009). The results of foreign SCGDs’ state researches are frequently published in ICOLD booklets; researches of the state of 287 SCGDs in Norway are generalized in scientific literature (Jensen, 2001). On the basis of these researches, the main reinforced concrete deteriorations in the investigated dams and their causes were established: reinforcement corrosion (noticed in 19 % of researched dams), concrete corrosion (18 %), deteriorations caused by frost (50 %), concrete erosion (47 %), water leakage (21 %), deformations (20 %), concreting defects (43 %).

The aim of this research paper is to investigate and to evaluate the state of spillway concrete gravity dams in Kėdainiai district municipality and Marijampolė municipality and to compare the results with those of previous years.
Methods of research

Object of research. According to the previous researches (1999-2005) carried out by the specialists of the Department of Building Constructions in ASU, SCGDs which supposedly have concrete and reinforcement deteriorations were chosen. During the period between 2005 and 2012, the scientific expeditions were organized in order to investigate SCGD spillways’ constructions of ten hydroschemes in Marijampolė and Kėdainiai districts. Taking into account the materials used for construction, the acting head and ground soil, the investigated objects belong to the impact classes CC1 and CC2.

The following constructions’ diagnostic methods were used during the investigation of deteriorations’ state changes in spillways:

1. documentation review;
2. visual examination;
3. nondestructive (instrumental) method used for the estimation of strength of concrete.

Documentation review – the analysis of design (work drawings and construction projects) and other archival documentation (technical maintenance records, rules of dam maintenance, inspections reports).

Visual examination is the inspection of an object carried out by an experienced specialist, who also makes the necessary measurements using a sheet of paper, writing materials, a ruler, a tape-measure, a sliding caliper and a camera. Using these tools, the location of damaged constructions, the types of deteriorations and their geometrical data (area, depth) were determined.

Nondestructive (instrumental) method is the method for the estimation of concrete compressive strength using a device of Schmidt’s system Cat.58-CO181/N. In accordance with the method given in LST EN 12504-2:2012, 10-12 hits were made in specially prepared construction’s places using a rebound hammer of concrete. Dry areas of concrete surface were chosen for the test. The hits were made in a way that the distances between the marks were no less than 30 mm. SCGD’s average compressive strength of concrete $f_{cm}$ was established in accordance with the special diagrams of devices’ calibration. Having statistically processed research results with the computer program MS EXCEL and having evaluated the statistical data (variation coefficient $\nu$), the compressive concrete class of SCGD concrete was established.

Having in mind construction’s average compressive strength $f_{cm}$ and the average root-mean-square deviation $\sigma$ (in accordance with LST EN 206-1:2002 the established reliability coefficient is 1.48) the characteristic compressive strength of concrete, $f_{ck}$ [MPa] was calculated with the probability of 95 % by the following formula:

$$f_{ck} = f_{cm}(1–1.48\sigma). \tag{1}$$

The C class according to the Standard STR 2.05.05:2005 of concrete was established by rounding down the meaning to the standard value.

The evaluation of technical state of spillways was given in points in accordance with the methodology given in Standard STR.1.12.03:2006. The state was being evaluated in points of defectiveness (risk) in the scale of 10 points (0 points – ideal state, 10 points – element’s emergency state) following evaluation criteria given in Standard STR 1.12.03:2006, appendix 2.

The HS state points were estimated according to the following criteria:

- either the element corresponds to set requirements or there are slight deviations from them – 0-2.0 points (good state);
- element’s deteriorations do not have a great influence on its strength and normal functioning – 2.1-4.0 points (average state);
- element’s deteriorations have a slight influence on its strength, reliability and durability – 4.1-6.0 points (satisfactory state)
- element’s deteriorations reduce considerably its strength and reliability 6.1–8.0 (unsatisfactory state);
- due to considerable deteriorations of the element its further use is impossible, possible failure of the structure 8.1-10.0 points (very bad state).

If one of main elements which determines HS reliability is evaluated from 8.1 to 10.0 defectiveness points, then the technical state of the whole hydraulic structure is evaluated by the same points. If the main elements with defectiveness points from 8.1 to 10.0 are absent, overall points ($B_u$) of HS technical state are calculated according to the following formula:

$$B_u = \frac{B_1 + B_2 + \ldots + B_n}{n}, \tag{2}$$

where $B_1, B_2, \ldots, B_n$ – evaluation points of separate HS elements;
$n$ – number of evaluated HS elements.

The calculated points of HS technical state ($B_u$) are rounded up or down in limits of 0.1.
Results and their review

During the field observations, the most damaged constructions, types of deteriorations and the main investigative characteristic i.e. compressive strength of concrete were determined. The following data is presented in the table 1: the year of hydrochemes investigation, the results of compressive strength of concrete of piers and abutments (Ab) and the class of compressive strength of investigated constructions’ concrete determined according to those results.

According to the research results given in table 1, it was established that the highest average compressive strength of concrete (36.5 MPa which corresponds to C25/30 concrete class) is in Antanavas SCGD constructions and the lowest rate (6.9 MPa, which is lower than minimal C6/7.5 compressive concrete class) was determined in Kazlai SCGD constructions. In comparison with earlier research results, the compressive strength of concrete decreased by one strength class in the constructions of Juodkiškiai, Marijampolė II and Kazlai SCGD.

Table 1. Results of the research of compressive strength of SCGD piers and abutments

<table>
<thead>
<tr>
<th>No</th>
<th>Name of hydroscheme, year of construction (name of researched construction)</th>
<th>Year of research</th>
<th>Average compressive strength of concrete $f_{ck}$, MPa</th>
<th>Variation coefficient v, %</th>
<th>Root-mean-square deviation $σ$, %</th>
<th>Characteristic compressive strength of concrete $f_{ck}$, MPa</th>
<th>Minimal class of compressive strength of concrete C</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Akademija – Dotnuva, 1968 (upper part of pier)</td>
<td>2009</td>
<td>33.0</td>
<td>14.7</td>
<td>4.4</td>
<td>28.1</td>
<td>C20/25</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2011</td>
<td>32.5</td>
<td>14.5</td>
<td>4.3</td>
<td>27.6</td>
<td>C20/25</td>
</tr>
<tr>
<td>2</td>
<td>Juodkiškiai, 1980 (left Ab of TW)</td>
<td>2005</td>
<td>29.7</td>
<td>25.7</td>
<td>3.5</td>
<td>25.3</td>
<td>C20/25</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2011</td>
<td>26.9</td>
<td>24.1</td>
<td>3.2</td>
<td>22.9</td>
<td>C16/20</td>
</tr>
<tr>
<td>3</td>
<td>Kėdainiai city, 1972 (right Ab of TW)</td>
<td>2008</td>
<td>12.6</td>
<td>24.4</td>
<td>3.1</td>
<td>9.7</td>
<td>C6/7.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2012</td>
<td>11.4</td>
<td>23.6</td>
<td>2.9</td>
<td>9.7</td>
<td>C6/7.5</td>
</tr>
<tr>
<td>4</td>
<td>Kruostas, 1953 (right Ab of TW)</td>
<td>2008</td>
<td>21.3</td>
<td>2.8</td>
<td>6.2</td>
<td>20.1</td>
<td>C16/20</td>
</tr>
<tr>
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<td></td>
<td>2012</td>
<td>20.8</td>
<td>2.7</td>
<td>5.9</td>
<td>20.7</td>
<td>C16/20</td>
</tr>
<tr>
<td>5</td>
<td>Labūnava, 1977 (upper part of pier)</td>
<td>2005</td>
<td>32.5</td>
<td>9.4</td>
<td>3.1</td>
<td>27.6</td>
<td>C20/25</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2012</td>
<td>31.8</td>
<td>9.1</td>
<td>2.9</td>
<td>27.0</td>
<td>C20/25</td>
</tr>
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</table>

Marijampolė municipality

<table>
<thead>
<tr>
<th>No</th>
<th>Name of hydroscheme, year of construction (name of researched construction)</th>
<th>Year of research</th>
<th>Average compressive strength of concrete $f_{ck}$, MPa</th>
<th>Variation coefficient v, %</th>
<th>Root-mean-square deviation $σ$, %</th>
<th>Characteristic compressive strength of concrete $f_{ck}$, MPa</th>
<th>Minimal class of compressive strength of concrete C</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>Antanavas, 1957 (upper part of pier)</td>
<td>1999</td>
<td>31.5</td>
<td>12.4</td>
<td>3.8</td>
<td>26.8</td>
<td>C20/25</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2011</td>
<td>36.5*</td>
<td>9.3</td>
<td>5.2</td>
<td>31.0</td>
<td>C25/30</td>
</tr>
<tr>
<td>7</td>
<td>Marijampolė I, 1957 (right Ab of TW)</td>
<td>2006</td>
<td>32.8</td>
<td>15.9</td>
<td>7.5</td>
<td>27.9</td>
<td>C20/25</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2011</td>
<td>31.4</td>
<td>15.7</td>
<td>7.3</td>
<td>26.7</td>
<td>C20/25</td>
</tr>
<tr>
<td>8</td>
<td>Marijampolė II, 1974 (left Ab of TW)</td>
<td>1999</td>
<td>13.5</td>
<td>29.1</td>
<td>6.6</td>
<td>11.5</td>
<td>C8/10</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2011</td>
<td>12.1</td>
<td>21.9</td>
<td>5.4</td>
<td>9.3</td>
<td>C6/7.5</td>
</tr>
<tr>
<td>9</td>
<td>Kazlai, 1991 (right Ab of TW)</td>
<td>1999</td>
<td>11.7</td>
<td>2.6</td>
<td>2.6</td>
<td>10.0</td>
<td>C8/10</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2004</td>
<td>6.9</td>
<td>9.6</td>
<td>0.66</td>
<td>5.7</td>
<td>&lt;C6/7.5</td>
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<tr>
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<td>Netičkampis, 1951 (Ab of TW)</td>
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<td>21.6</td>
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<td>3.6</td>
<td>20.2</td>
<td>C16/20</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2009</td>
<td>21.3</td>
<td>2.6</td>
<td>4.0</td>
<td>20.1</td>
<td>C16/20</td>
</tr>
</tbody>
</table>

Notations: TW – tail-water; Ab – abutment; * – reconstruction works

During the field observation, the main SCGD defects were determined; the technical state of spillways constructions was evaluated, defectiveness points were given and total points of SCGD technical state were calculated (Table 2) in accordance with deteriorations registered during the field observation and using the methodology given in Standard STR 1.12.03:2006. On purpose to evaluate the changes of the state a reference was made to the earlier results of the technical state evaluation of hydrochemes’ constructions, which were received during the research carried out in 1999-2005 by the specialists of the Department of Building Constructions in ASU.

Analyzing the results of pier constructions’ technical state research it was established that before reconstruction in Akademija-Dotnuva and Antanavas SCGDs (Fig.1), pier constructions had been in a very bad technical state (8.1-10.0) due to deteriorations of the elements, which made the further use of constructions impossible: the failure of the whole structure was possible. Currently, the constructions of Kruostas SCGD are considered to be in such situation. Before reconstruction in Marijampolė I and Marijampolė II dams, the state of piers had been evaluated as unsatisfactory (bad) i.e. respectively the evaluation of 8.0 and 6.0 points had been given: constructions’ defects which considerably
reduced their strength and reliability had been found. After reconstruction, the state of piers’ constructions in these SCGDs improved, however in hydroschemes, where the reconstruction haven’t taken place, the state of piers worsens, it has especially worsened in Netičkampis SCGD (7.3 points, unsatisfactory (bad) state).

Table 2. The evaluation of the state of piers, spillway base and outflow constructions in the researched SCGDs in accordance with the Standard STR 1.12.03:2006

<table>
<thead>
<tr>
<th>No</th>
<th>Name of hydroscheme, year of construction</th>
<th>Year of research (reconstruction works*)</th>
<th>State of piers, points</th>
<th>State of spillway base, points</th>
<th>State of outflow constructions, points</th>
<th>General evaluation of SCGD state Bu, points</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Akademija – Dotnuva, 1968</td>
<td>1999</td>
<td>9.0</td>
<td>7.0</td>
<td>9.0</td>
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<tr>
<td></td>
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<td>2006*</td>
<td>4.0</td>
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<td>4.0</td>
<td>4.0</td>
<td>6.0</td>
<td>4.6</td>
</tr>
<tr>
<td>2</td>
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Main piers’ deteriorations in the investigated SCGDs are the following: crumbled protective layer of concrete, its corrosion, reinforcement corrosion, cracks in concrete, chipped edges etc.

![Figure 1. Technical state of piers](image-url)
Analyzing the results of spillway base technical state research, it was established that before reconstruction in Akademija–Dotnuva and Antanavas SCGDs (Fig. 2), these constructions had been in an unsatisfactory (bad) technical state (6.5-7.0 points). Before reconstruction in Marijampolė I and Marijampolė II dams, the technical state of spillway basements had been evaluated as average (2.0-2.5 points) i.e. constructions’ defects which do not have a great influence on their strength and normal functioning had been found. The technical state of spillway basements was evaluated as average in those SCGDs, where the reconstruction haven’t taken place, still, the technical state of these constructions has especially worsened in Netičkampis SCGD (7.5 points, unsatisfactory (bad) state) and Kruostas SCGD where it has worsened from 5.5 points in 1999 to 10.0 points in 2005-2011. Main spillway constructions’ deteriorations in the investigated SCGDs are the following: concrete corrosion, bio-corrosion, concrete corrosion caused by cavitation etc.

Analyzing the results of outflow constructions’ state research it was found out that before reconstruction in Akademija – Dotnuva and Antanavas SCGDs (Fig. 3), these constructions had been in a very bad state (9.0 points) the failure of the whole structure was possible due to considerable deteriorations of constructions. The technical state of outflow constructions in other SCGDs was evaluated as unsatisfactory (6.1-8.0 points) and only in Labūnava and Kazlai SCGDs the technical state of these constructions was evaluated as satisfactory (4.1-6.0 points). The main deteriorations of outflow constructions noticed in all the investigated SCGDs are the signs of concrete corrosion. Deformations of retaining walls were noticed in Kėdainiai city, Marijampolė I and Netičkampis SCGDs. Similar deteriorations are mentioned in the generalized report of state researches of 287 SCGDs in Norway, which can be found in references (Jensen, 2001).

Figure 2. Technical state of spillway base

Figure 3. Technical state of outflow constructions
Having summarized the results of constructions’ technical state researches, a general evaluation of SCGDs’ state was calculated and compared with the results of previous researches (Fig. 4).

Comparing the research results carried out in 2005-2012 with those of previous years (1999-2005) it was found out that the technical state has hardly changed in Kruostas, Marijampolė II and Antanavas SCGDs; the technical state has worsened in Akademija-Dotnuva, Juodkiškiai, Kazlai and Netičkampis SCGDs; the state has improved due to reconstruction in Marijampolė I SCGD. The worst technical state was established in Kruostas (10.0 points) and Netičkampis (7.5 points) SCGDs. It is suggested to use methods and materials described in scientific literature (Leger et al., 1995; Korman et al., 2003; Guzii et al., 2013) for repairing damaged concrete surfaces and rehabilitation of SCGDs.

Conclusions

Having compared the results of research carried out in 2005-2012 with those of previous years (1999-2005) it was found out that the technical state has changed a little in Kėdainiai district municipality (Kruostas spillway concrete gravity dam) and in Marijampolė municipality (Marijampolė II and Antanavas SCGDs). The technical state has worsened in Kėdainiai district municipality (Akademija-Dotnuva, Juodkiškiai, Kazlai and Netičkampis SCGDs) and in Marijampolė municipality (Netičkampis SCGD). Due to reconstruction the technical state has improved only in Marijampolė I SCGD. The worst technical state was established in Kruostas (10.0 points) and Netičkampis (7.5 points) SCGDs.

Having summarized the results of SCGD research, it was established that the Kruostas SCGD is in the worst technical state (constructions are fragmented and do not function already, general evaluation of dam’s state is 10.0 points). The abutments of outflow constructions in Kėdainiai city, Marijampolė I and Netičkampis dams are deformed, consequently, their technical state is evaluated as unsatisfactory (bad). The technical state of other dams is evaluated as satisfactory (4.1 - 6.0 points), there were no considerable deteriorations.

The field observation of 10 SCGDs in Marijampolė city and Kėdainiai district municipalities has showed that the most frequently detected deteriorations are the following: crumbled protective layer of concrete (found in all the investigated dams), deformations (found in Kėdainiai city, Marijampolė I and Netičkampis dams), reinforcement corrosion (found in Antanavas, Netičkampis and Marijampolė I dams).

The highest average compressive strength of concrete (36.5 MPa, which corresponds to C25/30 class of concrete) was determined in Antanavas SCGD. The lowest result (6.9 MPa which is lower than C6/7.5 class of concrete) was determined in Kazlai dam. In comparison with the data of previous researches, the average compressive strength of concrete decreased by one class of strength in Juodkiškiai (from C20/25 to C16/20), Marijampolė II (from C8/10 to C6/7.5) and Kazlai (from C8/10 to C6/7.5) dams.
References

Damp Water Steam Impact on Fungi on Norway Spruce (Picea abies (L.) Karst.) Seeds

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Abstract

The development of economics and intensive technologies cause the increase of environmental pollution and demand of natural recourses. Sustainable and environment friendly methods became very important in forestry. The development of ecological methods in the forest management became an important task for future. The decreased use of pesticides affects positively forest ecosystem as well as global situation. One of the most widely applied measures to protect seeds from the damage caused by fungi is spreading theaters. Alternative is to use high temperature. All live organisms are destroyed in a high temperature environment. It is very important to find optimal treatment time of high temperature so that pathogenic organisms would be destroyed but germination characteristics of the seeds would remain unaffected. We investigated how a damp water steam affects fungi on Norway spruce (Picea abies (L.) H. Karst.) seed. Control seed’s set was not affected by damp water steam and contaminated Penicillium sp., Alternaria sp., Mucorales, Aspergillus sp ii Fusarium sp. fungi. Under the treatment of 1 second by damp water steam the fungi Fusarium sp was completely destroyed. Treatment by damp water steam from 2 till 4 seconds completely destroyed Mucorales, Aspergillus sp and infection of Penicillium sp., Alternaria sp fungi diminished from 63 till 18 times respectively. From 83.5% till 98.3% of fungi on the seeds were destroyed when the Norway spruce tissues heated from 59 ºC till 85 ºC.

Key words: Norway spruce, seeds, thermal treatment, pathogens, fungi

Introduction

An increased atmosphere pollution and climate change extensively affects the status of forest health. Climate changes (early frosts at autumn, late frosts at spring, positive temperature at winter, strong winds etc.) affects woody vegetation and in combination with other environmental agents creates a good environment for the new plant diseases pathogens (Dabkevičius et al. 2006). Fungal diseases of the Norway spruce (Picea abies (L.) H. Karst.) are not an exception.

The development of diseases mainly depends on temperature, humidity and nutrients. On the surface of seed there are lots of fungi diseases agents which use seed’s nutrients, emit micotoxins, quality and evolution of the seeds. The aim of all seed treatment methods is to control pathogens (Clear 2002). The benefit of seeds dipping is proved, however this method is not environmentally friendly. New ecological methods from pathogenic micro flora must be developed. They improve seeds quality, increase resistance for diseases and productivity (Dabkevičius and Kreimeris 1995; Vasiliauskiene 2002; Döll 2002). Hot water, sun energy, damp water steam, fire are effective ways of pathogens destruction (Agarwal and Sinclair 1989). Using of infrareds rays can diminished some of together with seeds spreading viruses (Soenartningsh 1996), bacterium (Grondeau and Samson 1994), nematodes (Tenente 1999) and fungies (Takano 1985). Seeds were studied after treatment by microwaves in 68-75 °C temperature (VonHoersten and Luecke 2001), low temperature plasma and magnetic field (Lynikiene 2006). More attention as most promising given to the thermal methods. Process of thermal methods based on the environments of various temperatures. Damp water steam is ecological high temperature environment that can fully replace pesticides. Special conditions are created to prepare seeds. In affected environment the temperature is about 100 ºC (Gimbutis 1993). Process of heat transmission is very intensive, steam condensation takes place on the seeds surface and the heat is given. Devices of damp water steam are very effective (Gimbutis 1993). The environments of high temperature water steam do not allow resisting for the live organisms. Thus there are no data about 100 ºC damp water steam impact to the spruce seeds viability.

Usually seed molds causes by saprophytic fungi. Sometimes molds may be caused by facultative parasites. It is possible to clime that nearly all seeds and fruits are affected. The main symptom of molds is superficial mycelium on infected tissues of seeds. The mycelium of mold fungi develops superficially. It does not influence seed germination power but it can destroy the seedcoat and penetrate interior tissue. Namely this effect is the cause for germination power reducing. It was detected that the molds of Norway spruce seeds may be caused by many different fungi genuses: Penicillium, Trichoderma, Trichothecium, Fusarium, Alternaria, Cladosporium, Aspergillus, Botrytis, Mucor etc. The look of these fungi is different but the final impact for the seeds is similar. The Norway spruce seeds which are infected by Alternaria tenuis Nees. has a reducing germination power and causes seeds and seedling rot and damping-off. The influence of Aspergillus niger like and Trichothecium roseum reducing germination power. Cladosporium herbarum also reduces germination power of seeds and causes mold of needles and leaves. Penicillium expansum kills the seeds. In fact Fusarium oxysporum can cause wilt diseases in more than 100 plant species (Armstrong and Armstrong, 1981), by reducing the germination power and causes seeds and seedlings rot and damping-off (Kuzmichev et al. 2000). Mucor spp., Rhizopus nigricans and Thamnidium elegans influence for Norway spruce seeds by delaying seed germination, however this pathogens had no effect on final germination percentage (Himanen et al. 2012).

Our study focused on the fungi genus Penicillium sp., Alternaria sp., Mucorales, Fusarium sp. These fungi genuses are the most common on Norway spruce seeds and seedlings and causes the biggest damage. The aim of our study was to test how the damp water steam affects the Norway spruce seeds and fungi pathogens.
Material and methods

The boiler of damp water steam was innovated in the Faculty of Agricultural Engineering ASU. The thermal treatment of Norway spruce seeds is based on the field of high temperature creation around the seed. This field of high temperature is created by damp water steam which blasting to the atmosphere on pressure of 0.5 bar. Temperature of damp water steam is 100 °C so it condensates on the surface of the seeds and gives the heat of condensation for the seed. Intensive heating of seeds provided.

During the experiment we affected the Norway spruce seeds by damp water steam in different time intervals: 1, 2, 3, 4 seconds. Control of this research was not affected by damp water steam. 5 samples of the Norway spruce seeds (5g each) were prepared for each treatment time. We tested 25 samples in total. Seeds were spread on the grid for the equal impact. Damp water steam was at 1 cm high over the samples. After the treatment by damp water steam seeds were put to the plastic bags to keep them safe from the environmental impacts.

Temperature permeability was indicated in the seed. Seeds from the samples were selected randomly. Then thermopores of 0.07 mm were inserted to those seeds. The aim was to investigate how temperature is changing in the seeds’ tissues (Fig. 1). We took 10 seeds for each damp water steam treatment time. Experiment was repeated 5 times. In total 250 seeds were measured. Changes of temperature in the tissues were recorded by a special device ALMEMO 2590-9.

Figure 1. Measurement of the temperature in the Norway spruce seed. 1-seed, 2, 3-termocouples

Phytopathological analysis of seeds treated by damp water steam was done in the laboratory of Forest trees seeds and samplings quality. Specially prepared Chapek-Doks medium was used for the research. Medium was put to the aseptic Petri plates in the aseptic environment. For the growth of fungi used 9 cm diameter Petri plates. 20 ml of medium was put to each plate to make 2–3 mm thickness layer become congeal. After preparation of the substrate the randomly taken Norway spruce seeds treated by damp water steam and put in Petri plates. In each plate was put 50 seeds; 2 mm one from another. For every treatment time we composed 5 samples, 250 seeds in total for each treatment time. Petri plates with seeds were put to generation machines CLIMAS and kept in the constant temperature (28 °C) for 7 days. Phytopathological analysis performed by a special mythologist (ГОСТ, 1976). The fungal diseases pathogens Penicillium sp., Alternaria sp., Murocales, Aspergillus sp and Fusarium sp. resisted for the high temperature environment were identified during study. Control of the research was not treated by damp water steam.

We used nested ANOVA design to test how damp water steam affected fungi. Treatment type were nested in fungi sp.

Results and discussion

Different time treatment by damp water steam had a significant effect (F=9.41; p<0.0001) for the seeds infection by fungi (Fig. 2). Treatment time was very important. The analysis of control sample showed that seeds infection by different fungi genus is great. In control sample the Penicillium sp. genus fungi were indicated in 76% of examined seeds, Alternaria sp. – in 20.4%, Murocales – 15.6%, Aspergillus sp – 2.4% as well as Fusarium sp. – 1.2%. One seed may be infected by all these fungi.
After the treatment of 1 second by damp water steam the \textit{Penicillium sp.} diminished by 3.7 times comparing with control sample. After 2, 3 and 4 seconds of treatment by damp water steam the fungi was 4.9-63.3 times less. The fungi \textit{Alternaria sp.} diminished from 6.8-22.0 times in all treatment times. After 1 second treatment by damp water steam \textit{Mucorales} fungi declined by 90.1\%. Further 2, 3 and 4 seconds treatment causes total extinction of \textit{Mucorales}. Similar effect observed with \textit{Aspergillus niger} genus fungi: after 1 second treatment they diminished 85.7\% and later extinct at all. The nested ANOVA results shows that are significant differences among different treatment times and infected seeds (\(F=9.41, p<0.0001\)). The genus \textit{Fusarium sp.} fungi extinct at all after any time of the treatment by damp water steam (Fig. 3).

Seeking to change the chemical seeds treatment to the environmental friendly damp water steam treatment we detected that fungal diseases pathogens destruction depends on changes of temperature in Norway spruce seeds tissues (Fig. 4). After 1 second treatment by damp water steam temperature of seed tissues rise till 59 °C; 83.5 \% of fungal diseases pathogens were destroyed. After 2 seconds treatment temperature of seed tissues rise till 72 °C and 90.7 \% of fungal diseases pathogens were destroyed. After 3 seconds treatment temperature was 78 °C and 95.9 \% pathogens destroyed. Finally, after 4 seconds – temperature was 85 °C and 98.3\% pathogens destroyed.

\textbf{Conclusions}

Control sample was not treated by damp water steam and the study in the laboratory showed high infection level by \textit{Penicillium sp.}, \textit{Alternaria sp.}, \textit{Mucorales}, \textit{Aspergillus sp} it \textit{Fusarium sp.} genus fungi. After any time treatment by damp water steam \textit{Fusarium sp.} genus fungi extinct at all. After treatment by damp water steam from 2 till 4 seconds \textit{Mucorales}, \textit{Aspergillus sp} genus fungi vanished, infection by \textit{Penicillium sp.}, \textit{Alternaria sp} diminished 63 and 18 times
respectively to compare with control sample. From 83.5% till 98.3% of fungal diseases pathogens were destroyed when temperature of Norway spruce seeds’ tissues reached from 59 ºC till 85 ºC.

Figure 4. Temperature changes of Norway spruce seeds tissues

References


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The Quality of Wolf Population in Lithuania According to Hunting in 2005-2013

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Abstract
Wolf hunting is limited in Lithuania from 2005. However selective hunting is not carried out. Due to this harvested wolves are random representatives of population. Age ratio of hunted wolves was: 26.8% immature wolves, 73.2% mature; sex ratio was: 66.5% males and 33.5% females. The ratio between harvested males and females was 1.98:1. The large part of wolf population in Lithuania consisted of healthy wolves (78.9%), but diseases of skin were noticed in 30.6% of municipalities where wolves were hunted. Comparing eight hunting seasons the diseases of skin were most broadly spread in country in the last hunting season (2012-2013). During eight hunting seasons wolves were hunted in 36 districts, which are 72.6% of all districts in Lithuania. It has been determined that the greatest numbers of the wolves (79.5%) were harvested incidentally, i.e. during the hunting of other game animals. Usually wolves were hunted by driving hunting (56.8%), blind hunting (33.2%) and flagging (7.9%). Besides there were recorded five cases of wolves found in snares. Seven cases were also recorded where harvested wolves were carrying snares on their bodies. The aim of this work is to evaluate the quality and distribution of the wolf’s population in Lithuania according to wolves hunting in 2005-2013 period.

Key words: wolf, Lithuania, hunting, distribution

Introduction
The hunting is direct anthropogenic factor (Belova, 2001). According disturbance intensity the hunting is attributed to temporary disturbance (Lõhmus, 2001). People were interested in wolves, as objects of hunting, in Lithuania long time ago (Žumbakys, 1993). The methods and intensity of the wolf’s hunting varied a lot. Until the middle of last century the wolves were exterminated (Elisonas J. 1925; Данилов, 1945; Козлов, 1955; Рябов, 1957; Юркштас, 1980; Разумовский, 1981; Сабанеев, 1988); now wolf’s populations are being controlled under scientific based methods (Бибиков, 1989; Okarma, 1993; Lõhmus, 2001; Ozoliņš, Andersone, 2001; Ozoliņš et al., 2001; Ozoliņš et al., 2008; Wolf Population..., 2009) and in some other countries wolf hunting is forbidden (Salvatori, Linnell, 2005). In those countries where wolves are still hunted, according the laws just few hunting techniques permitted, the hunting period is limited and hunting quantity limit is determined.

There has been determined wolf’s hunting quantity limit in Lithuania since 2005 (Del Lietuvos Respublikos... 2005). This hunting quantity limit is assigned to all territory of the country. Traditionally wolf is a desirable catch of the hunters in Lithuania. Selective hunting is not carried out. Due to these causes hunted wolves are random representatives of population. It can be asserted that hunted wolves reflect the quality of population in all country, and hunted areas reflect the distribution of the wolves in Lithuania.

At present, furthermore, wolves are hunted during legal and illegal huntings, due to human fault wolves get hit by cars (Balčiauskas, Balčiauskienė, 2008) or trains, get into loops or snare traps (Andersone, Ozoliņš, 2000; Павлов, 1990; Patapavičius, 2002), or are hunted by mistake. Such cases were determined during collection the data.

The aim of this work is to evaluate the quality and distribution of the wolf’s population in Lithuania according to wolves hunting in 2005-2013 period.

Methods
The quality of the wolf population in Lithuania was investigated using data of wolves hunted throughout Lithuania during the hunting seasons from 2005/2006 to 2012/2013. The basic wolf hunting data was taken from the official reports of the Ministry of Environment (Lietuvos..., 2006; Lietuvos..., 2007; Medžiojamųjų..., 2008; www.am.lt). In order to obtain more detailed information, the survey of hunters was made.

The age and gender were established for a total of 171 wolves harvested. Individuals were aged as follows: immature (yearlings, juveniles) and mature wolves (older than two years of age); the gender was determined in all groups. During the examination, there was no possibility to determine the precise age of a mature wolf. To evaluate the gender ratios, a χ² (Chi-squared) test was performed for 2 x 2 rate tables (Statistica 8.0).

The data about wellness of harvested wolves were collected. Only externally visible diseases and injuries were recorded.

Areas, where wolves were hunted, analyzed with GIS. Using spatial statistics, a link between the spots of wolf hunting was established (Mitchell, 2005).

While analysing this information, fluctuations in the annual hunting bag at a district level were reviewed. With GIS there was done local cluster analysis, which is looking for clustering objects on a spatial local level, in this case – consisting of municipalities with meaningful local Moran’s I values.

According to the intended target of hunting, hunting was divided into the specialised hunting of wolves and the general hunting of other game animals.

Hunting is also divided into categories according to its method, i.e., driving hunting, blind hunting, stalking, silent driving, chain driving hunting, circular driving hunting, hunting with hounds, hunting with birds of prey, trapping, hunting with catchers, flagging (Medžiojamūs..., 2010).

Information is also provided regarding reported illegal hunting.
Results and discussion

It has been established that among the harvested wolves, males consist of 66.5%. The ratio between harvested males and females was 1.98:1. A statistically reliable difference from the ratio of 1:1 (chi-square $\chi^2 = 8.60$; d.f. = 1; $p = 0.034$) between the genders was determined. Males constituted 66.9% of immature and 66.3% of mature ones. Statistically, this difference was not reliable (chi-squared $\chi^2 = 0.15$; d.f. = 1; $p = 0.7015$). Immature wolves accounted for 26.8% of the all examined. Comparing data of analyzed period with 1950-1958 and 1978-1982 years state (1.33 : 1) (Prūsaitė, 1961 a, b, 1988), it’s seen male wolf numerical superiority. It should be noticed that existing state is not exceptional comparing with neighbor and distant countries (Бибиков, 1985, Okarma, 1989, Andersone et al., 2001, Valdmann et al., 2004) – male wolf quantity normally is two times larger in the population.

73.2% wolves were included into the group termed ‘mature’. Some preliminary conclusions about age may be made on the basis of the general appearance of the skulls in the collected material. Thus, it has been determined that young grown-up wolves consist of 76.3% mature wolves, middle-aged individuals – 14.4% and old individuals – 9.3%.

Healthy wolves made the greater proportion (78.9%) of the harvested wolves (Figure 1). 11.6% of the wolves had various injuries, most often old and healed wounds (81.8 %). New wounds were observed only in 4 wolves. Inspecting the bodies of the hunted wolves, 18 cases (9.5 %) were recorded where the animals had diseases of skin, like mange; these animals had been harvested in 11 of the 36 municipalities, where wolves were harvested during the examination period. In the last hunting season (2012-2013) the diseases of skin were most broadly spread by municipalities (Table 1).

![Figure 1. Wellness of harvested wolves during hunting seasons from 2005/2006 to 2012/2013 in whole territory of Lithuania](image)

Table 1. Morbidity of skin diseases in harvested wolves during hunting seasons from 2005/2006 to 2012/2013 in whole territory of Lithuania

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</tr>
<tr>
<td>2012-2013</td>
<td>7</td>
<td>16.3</td>
<td>Lazdijai (2), Kupiškis (1), Rokiškis (1), Telšiai (1), Ukmergė (1), Varėna (1)</td>
</tr>
</tbody>
</table>

Based on the collected data, the exact places of wolf harvest were cartographed (Figure 2). 96.6% of all wolves harvested during the hunting seasons from 2005/2006 to 2012/2013 were transferred to the map and used to perform further examination.

Taking all eight hunting seasons examined in general, spatial autocorrelation shows that the locations of the wolf hunts are in clusters. The „Nearest Neighbour“ value is equal to 0.433, and the calculated value of Z statistics of 14.428 show that the probability ($p = 0.000$) that the clusters were obtained randomly was less than 1% (when $Z < -1.96$, the clusterization is statistically reliable).
Within the period of the hunting seasons from 2005/2006 to 2012/2013, 236 wolves were hunted. The hunt was stopped due to yearly reached limit before the end of hunting season. The variation of hunted predators during the season remains unknown in limited wolf hunting period.

During eight hunting seasons wolves were hunted in 36 districts, what is 72.0% of all district in Lithuania. Largest wolves’ number was hunted in the Varėna district municipality (23 individuals), Biržai (17), Kupiškis (15). Such results can be explained by uneven distribution of predators’ density in the country’s territory.

There was made the local cluster analysis in the level of municipalities (Figure 3). According to the number of wolves hunted during hunting seasons 2005/2006 to 2012/2013 there were selected those municipalities, which local Moran’s $I$ was statistically meaningful. There was defined positive local Moran’s $I$ statistics in Biržai and Kupiškis districts’ municipality, which shows high value of attribute when attribute’s values in neighbor municipalities are high as well (HH). In the municipalities of Varėna and Marijampolė there was defined meaningful negative Moran’s $I$ statistics, showing high value of attribute, when in neighbor municipalities attribute value was low (HL); Moran’s $I$ statistics was -0.0038, value of Z statistics 0.1693 (p = 0.8656).

The greatest numbers of the wolves (79.5%) were harvested incidentally, i.e. during the hunting of other game animals. Of all huntings when wolf (-ves) was (were) harvested, it has been determined that 1.17 of a wolf (min-max = 1-4; moda = 1) in average was harvested during one hunting. During successful huntings 69.7% (SD = 33.7; CV = 48.98) of all the wolves encountered during the hunting were harvested.

In the course of eight seasons under consideration, 39 special wolf hunts were arranged, during which wolves were harvested. From one to four wolves were harvesting in special wolf hunts; 1.39 wolves on average (moda = 1). 57.4% (SD = 29.0; CV = 50.75) of all the wolves encountered were harvested in special hunts.

During the period examined, wolves were harvested via six methods of hunting: by driving hunting (56.8%), blind hunting (33.2%), flagging (7.9%), stalking (1.1%), silent driving (0.5%) and driving hunting with hounds (0.5%) (Figure 4). When hunting by driving, 1.24 wolves were harvested on average (of those cases where wolves were harvested).
The level of success in hunting was 62.9% (the proportion of wolves harvested against all encountered wolves during the hunt). Though wolves were usually hunt by driving, but there were just 9.9% of cases when driving hunting was arranged specially for wolf hunting. The average number of wolves harvested by blind hunting was 1.1, with a level of success of 75.3%. During flagging, the average number of the wolves harvested was 2.0 and the success rate was 69.4%. But only four successful hunts with flags were held during eight hunting seasons.

Illegal hunting is an anthropogenic factor that is difficult to quantify. Five cases of wolves found in snares were recorded during the period examined. These cases were observed in Akmenė, Joniškis, Mažeikiai and Šakiai districts. Seven cases were also recorded where harvested wolves were carrying snares on their bodies.

Conclusions

Hunted wolves sex ratio was 66.5% males and 33.5% females; age ratio was 26.8% immature wolves, 73.2% mature. The distribution of hunted individuals according age and sex ratio partly shows the structure of wolf population in the nature.

The large part of wolf population in Lithuania consisted of healthy wolves (78.9%), but diseases of skin were noticed in 30.6% of municipalities where wolves were hunted.

Usually wolves were hunted by driving hunting (56.8%), blind hunting (33.2%) and flagging (7.9%). It has been determined that the greatest numbers of the wolves (79.5%) were harvested incidentally. The hunting considering animals’ quality indexes or density distribution is not being organized.

Visually wolves were hunted in all territory of the country, however GIS cluster analysis showed that hunted places laid out in groups (p = 0.000), what means, that there were territories where living conditions for the wolves were more acceptable.

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Comparison of Standardized Precipitation and Selyaninov Hydrothermal Drought Indices

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Abstract

A lot of recent works have been done for development of drought indices as well as to review theirs application and comparison of their advantages and drawbacks. The Standardized Precipitation Index was proposed to characterize meteorological droughts from 2009 by World Meteorological Organization. Selyaninov’s hydrothermal coefficient is used to evaluate the agro-climatological conditions in some European countries and it is confirmed to be a drought index in Lithuania. The purpose of investigation was to compare the Standardized Precipitation Index (SPI) as the reference drought index accepted by the World Meteorological Organization and the Selyaninov’s hydrothermal coefficient (HTC) as the main drought index used in Lithuania. Assessment of vegetation period during 2003-2012 (May–September) according HTC indicated 70 % as wet periods (2004 - 2007, 2010- 2012) and 30 % as enough humid (2003, 2008, 2009), there were no dry periods indicated. Assessment according SPI indicated 90 % near normal of all periods (2003-2009 and 2011-2012), moderately wet was period of 2010. Evaluation of one month time scale periods according HTC and SPI1 differed in 39 of the 50 cases (78 %). Excessively wet and optimally wet according HTC were 52 % and 24 % accordingly. According SPI1 very wet and moderately wet were identified 8 and 16 % of total months accordingly. There was no month evaluated as extremely wet. According HTC as weak dry were identified 52 % of all months, according SPI1 72 proc. were identified as near normal. It was found out the very strong correlation (r=0.855) between HTC and SPI1, thought the rating of values according HTC and SPI1 differed. HTC < 0.7 equals to SPI1 < -1.4 and HTC < 0.5 equals to 1.8. The biggest differences determined during humid and wet periods.

Introduction

Drought is among the most complex climatic phenomena affecting society and the environment (Wilhite, 1993). In general, drought can be categorized into meteorological or climatological, agricultural, hydrological, and socio-economic drought based on its time scale and impacts (Heim, 2002). This complexity is related to the difficulty of quantifying drought severity since the drought is identified by its effects or impacts on different types of systems, and there is not a physical variable we can measure to quantify droughts (Vicente-Serrano et al., 2012). Drought can be monitored effectively using drought indices such as the Palmer Drought Severity Index (PDSI), Palmer, (1965), the Standardized Precipitation Index (SPI; McKee et al., 1993, 1995) calculated with in-situ meteorological data from weather stations or others. A drought index value is typically a single number and is more useful than raw data for decision-making (Altman, 2012). A lot of recent works have been done for development of drought indices as well as to review their application and comparison of their advantages and drawbacks (Sivakumar et al, 2011). Drought indices have evolved from simplistic approaches based on some measure of rainfall deficiency, to more complex problem-specific models (Heim, 2002), anyway still no one definition covers all possible forms of drought and no one index can possibly capture all the various definitions (Svoboda et.al., 2004). It is a difficult to assess droughts due to variations in temporal and spatial extents of the complex events and their severity, there is no universal drought indicator and previous studies identified significant discrepancies between the drought indices (Altman, 2012).

Currently to monitor drought conditions drought indices are used in real time manner that is easily understood by end users (Svoboda et al., 2002; Shukla et al., 2011). The Standardized Precipitation Index (SPI) was proposed by McKee et al. (1993) and it has been increasingly used during the last decades because of its solid theoretical development, robustness and versatility in drought analyses (Redmond, 2002). The SPI uses only precipitation data, and can be obtained for flexible time scales by aggregating precipitation amount using a temporally moving window. Through a standardization process, SPI values may be comparable over space and time. Several studies have also demonstrated variation in the response of agricultural drought (Vicente-Serrano et al., 2006; Quiring and Ganesh, 2010). Practitioners prefer to get hands on indices that are simple to apply and as specific as possible to their crops (Niemeyer, 2008). Here, specific drought indices are required in order to define indicators, thresholds, and triggers for practical management of water resources in case of drought. These indices have to describe best the local and regional conditions of the hydrological cycle, and have to comply with the already available data that are measured routinely (Niemeyer 2008).

For many years in Lithuania, the humidity of vegetation period has been described using Selyaninov’s hydrothermal coefficient (HTC). According to Farago’s classification, it belongs to drought indices of water balance group “supply/demand” (Faraogo et al., 1989) as it uses daily values of precipitation and air temperature for the calculation of the period. According research done in Lithuania HTC, does not demonstrate the actual role of meteorological conditions in plant growth (Daugeliene and Zekoniene, 2009), it would be expedient either to modify the methodology for calculation or to search for more appropriate calculation methods. HTC does not consider soil moisture, thus period of medium humidity is often evaluated as dry if there was a wet period before it or contrary (Taparauskiene, 2009). Despite the limitations of Selyaninov’s hydrothermal coefficient, it is still used for the evaluation of the humidity of period in the Lithuanian climatic conditions and it is confirmed to be a drought index by the Lithuanian Government’s decision.

The National Meteorological and Hydrological Services (NMHSs) around the world are encouraged by World Meteorological Organization to use the Standardized Precipitation Index (SPI) to characterize meteorological droughts from 2009. Thus it is important to understand the accordance of SPI with other used indices. Drought indices under Lithuanian climatic conditions were compared by few researches. Valiukas (2011) found that during summer periods in Vilnius SPI identified less than half of droughts identified by HTC.
The purpose of investigation was to compare the Standardized Precipitation Index (SPI) as the reference drought index accepted by the World Meteorological Organization and the Selyaninov’s hydrothermal coefficient (HTC) as the main drought index used in Lithuania by evaluation of theirs accordance.

Methods

We have used the two most widely drought indices regionally. On the one hand, the HTC drought indices that are currently implemented in Lithuanian drought monitoring system, and the Standardized Precipitation Index (SPI), accepted by the World Meteorological Organization as the reference drought index for more effective drought monitoring and climate risk management (Hayes et al., 2011).

Drought indices were calculated using the monthly precipitation and mean temperature dataset during May – September registered at the Meteorological station in Kaunas, the geographical position corresponds to 54°88’ NL and 23°09’ EL. Evaluation of indices accordance was done for period of 2003-2012.

The Selyaninov’s hydrothermal coefficient (HTC) was calculated according (Dirse et all., 1984):

\[
HTC = \frac{H}{0.1 \cdot \sum T_{10}}
\]

where \( H \) – precipitation amount of estimated period mm;
\( T_{10} \) – the sum of average air temperature (>10 °C) at the same period, °C.

The value of HTC < 0.3 – means very dry; 0.4-0.5 – dry; 0.6-0.7 – middle dry; 0.8-1.0 – not enough humid; 1.0-1.5 – enough humid, > 1.5 - wet (Dirse et all., 1984).

The SPI calculation is based on the long-term precipitation record for a particular location and long-term period. For investigation used period of 2003-2012. SPI is calculated using special software (National.., 2013). Usually, the different hydrological, ecological and agricultural systems respond to different drought time scales due to the varied strategies of natural vegetation and crops to cope with water deficit (Chaves et al., 2003) or the different lithologic, land cover and/or water management regimes in the case of streamflow data (López-Moreno et al., 2012). The seasonal time scales of 3- month and 6-month are most appropriate if the major interest of study is agricultural drought (Rouault & Richard, 2003). As the highest correlation between SPI3 and summer HTC and between one-month HTC and SPI1 have been reported in Lithuania (Valiukas, 2011). Therefore, the SPI were calculated at different time scales from 1 up to 48 months (data are not presented) and in this study the priority was given to SPI1. Assessment was done summarizing fifty months data.

Results

The values of HTC and SPI counted for total vegetation period in 2003-2012 shown in figure 1. As it can be seen HTC changes from 1.21 in 2008 to 1.98 in 2010 and SPI – from -0.34 in 2008 to 1.12 in 2010. Assessment according HTC indicated 70 % as wet periods (2004 - 2007, 2010- 2012) and 30 % as enough humid (2003, 2008, 2009), there were no dry periods indicated. Assessment according SPI and HTC differed as according SPI were indicated 90 % near normal of all periods (2003-2009 and 2011-2012), moderately wet was period of 2010.

![Figure 1. Drought indeces of vegetation period during 2003-2012](image)

Figure 1. Drought indeces of vegetation period during 2003-2012

Note: According to HTC, < 0.3 – very dry; 0.4-0.5 – dry; 0.6-0.7 – middle dry; 0.8-1.0 – not enough humid; 1.0-1.5 – enough humid, > 1.5 – wet. According to SPI, ≤-2 – extremely dry, -1.5-(-1.99) – severely dry, -1.4-(-1.49) – moderately dry, -0.99-0.99 – near normal, 1.0-1.49 – moderately wet, 1.5-1.99 – very wet, ≥2.0 – extremely wet

In order to assess agricultural drought and plant water status it is needed to evaluate different time scales as the rainfall distribution differs a lot during separate month. Therefore, the next step was to calculate and assess HTC and SPI values for one month period. Evaluation of one month time scale periods differed in 39 of the 50 cases (78 %), what shown that identification of the same period drought level is different according HTC and SPI1. The best coincidence was between dry periods: according HTC identified as dry 2 % of all month, according SPI1 – extremely dry 2 % and moderately dry – 2 %. Anyway it cannot be assumed as a rule as the period of investigation was more humid as dry in total and in order to prove this tendency should be investigated longer period with lack of precipitation.
The largest variance was during normal and wet periods. Excessively wet and optimally wet according HTC were 52 % and 24 % accordingly. According SPI1 very wet and moderately wet were identified 8 and 16 % of total months accordingly. There was no month evaluated as extremely wet. According HTC as weak dry were identified 52 % of all months, according SPI1 72 proc. were identified as near normal.

Figure 2. The distribution of Drought indices monthly values during 2003-2012

The comparison of drought indices is complicated due to different methodological approaches. The first difference is between ratings of values. SPI is rated to seven levels, HTC – to six. Wet period’s identification according SPI is more detailed, while the HTC – counts only excessively wet periods. The next SPI do not consider the beginning of active vegetation and if the actual vegetation starts in the middle of month SPI takes into account monthly precipitation values. Differently HTC is calculated from period when average air temperature is higher as 10 °C for three days and consider daily precipitation rate. During period of investigation the earliest beginning of active vegetation started at the end of March. This is at least 5-10 days earlier as annual average of many years. Earlier as normal, vegetation started in 2004-2005, 2009.

In order to evaluate the equivalence of HTC and SPI1 was made correlation analysis (fig.3). It was found out the very strong correlation \( r=0.855 \) between HTC and SPI1. Similar results were reported by Valiukas (2011). He stated strong significant correlation between monthly values of SPI1 and HTC, as well as values of June – August of SPI with HTC for the same period. Anyway our results show the rating of values according HTC and SPI1 and identification of periods differs (fig. 3)

Figure 3. The relationship between Selyaninov hydrothermal coefficient (HTC) and Standardized Precipitation index (SPI)

Note: According to HTC, < 0.3 – very dry; 0.4-0.5 – dry; 0.6-0.7 – middle dry; 0.8-1.0 – not enough humid; 1.0-1.5 – enough humid, > 1.5 – wet. According to SPI, ≤ -2 – extremely dry, -1.5-(-1.99) – severely dry, -1(-1.49) – moderately dry, -0.99-0.99 – near normal, 1.0-1.49 – moderately wet, 1.5-1.99 – very wet, ≥2.0 – extremely wet

The values officially confirmed in Lithuania as indicating drought HTC < 0.5 (dry) and HTC < 0.7 (middle dry), according Valiukas (2011) results equals to SPI1 <-1.5 and SPI < -2.0 accordingly. Our study shows that HTC < 0.7 equals to SPI1 < -1.4 and HTC < 0.5 equals to 1.8. As mentioned before the biggest differences determined during humid and wet periods. According to the dependence (fig.3) the SPI at near normal (0.2 – 0.99) are identified as wet according HTC (1 – 1.5). There were identifies 13 such cases. From the dependency it can be seen that periods according SPI1 identified as near normal, according HTC are identified as not enough humid or middle dry, eg if the period according HTC is identified not enough humid (0.8-1.0), according SPI1 – it is counted as near normal.
It is difficult to assess which index indicates drought better. It was stated that HTC tends to overestimate as dry or wet periods, i.e. moderate humid periods are evaluated as dry or wet (Taparaskeviene, 2009). Similar results confirmed by drought review done in 1961-1995 (Buitkuvienė, 1998).

For successful application of the standardized precipitation index in future necessary to assess the rating scale in compliance with Lithuanian Climatic conditions as well as to compare it with the actual data. As the SPI is recommended by WMO as reference drought index it is essential to integrate SPI with productive soil moisture content and to find the ways of SPI application to agricultural drought monitoring.

Conclusions

Assessment of vegetation period during 2003-2012 (May – September) according HTC indicated 70 % as wet periods and 30 % as enough humid, there were no dry periods indicated. Assessment according SPI indicated 90 % near normal of all periods, moderately wet – 10 %. Identification of humidity / drought according HTC and SPI1 for one month time scale periods differed in 39 of the 50 cases (78 %). Excessively wet and optimally wet according HTC were 52 % and 24 % accordingly. According SPI1 very wet and moderately wet were identified 8 and 16 % of total months accordingly. There was no month evaluated as extremely wet. According HTC as weak dry were identified 52 % of all months, according SPI1 72 proc. were identified as near normal.

It was found out the very strong significant correlation (r=0,855) between HTC and SPI1, though the rating of values according HTC and SPI1 differed. HTC < 0.7 equals to SPI1 < -1.4 and HTC < 0.5 equals to 1.8. The biggest differences determined during humid and wet periods. According to the dependence the SPI at near normal (0.2 – 0.99) are identified as wet according HTC (-1.5).

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Sediment Retention in the Floodplain Areas of the Nemunas Catchment.

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Abstract

Due to the erosion of the arable surface about 483\,000 t/year of soil particles are washed in the Lithuanian territory of the River Nemunas catchment. The main part of this nutrient mud is retained on the grassed surfaces in gullies and sinks, and only less than 5% of these fine sediments occur in rivers and can be transported downstream into the Curonian Lagoon and the Baltic Sea. They may be intensively accumulated on the sacrificial bottom layer and have markedly negative effect on the environment here.

The sedimentation processes in the Nemunas delta, the Curonian Lagoon and the river catchment have been analyzed and the mathematical modeling of the flood activities covering the period of 1950–1991 has been done. It was established that about 3.56 million t/year of sediments were brought by the Nemunas River. About 80% of this amount was deposited and retained in the grassed floodplains. Hydraulic sediment retention and nitrogen removal measures and pollution reduction possibilities are discussed in the paper.

Key words: floodplains, hydraulic mathematical modeling, river Nemunas, sediment deposition and retention.

Introduction

The Baltic Sea, the Curonian Lagoon and the Nemunas River are complex eco-hydraulic systems with many interacting processes. The total area of the Lagoon is about 1600 km$^2$, total volume of the water is 62.6 km$^3$, and average depth is 3.8 m. Hydro-dynamically the Curonian Lagoon can be divided into 2 parts: the northern part, which is more influenced by the Nemunas River inputs, and the southern part, which can be classified as a sediment accumulation area. About 3.2 nm sediments deposited annually in the zones of mud accumulation (Pustelnikovas and Gulbinskas, 2002). The fine dispersed material in particulate form which is transported by rivers and gets settled on the Lagoon’s bottom accumulates from 70 to 98% of soil pollutants. (Galkus 2004). As a matter of fact, the intensity of thin dispersion material sedimentation is maximal in areas of mud sediments. This sediment accumulation and distribution of the polluted sediments as well as shallow bar formation and the Lagoon’s sinks mainly depend on hydrodynamics of the river Nemunas.

The river Nemunas which basin covers an area of 98,760 km$^2$, is the fourth largest influent to enter the Baltic Sea via the Curonian Lagoon. In Lithuania is 48% of the river length, draining more than 47% of the country. The river has 600 km$^2$ of floodplains. The density of the hydrographical network of the Nemunas basin in Lithuania is 1.10 km$^{-2}$, and 82% of this network is either regulated or employed as drainage channels. They are maintained as water receivers from drained lands and cover the greatest part of the river basin, collecting the polluted fine sediments from all diffused sources.

Part of these erosion products can be retained in the catchment’s area or transported into these channels as wash load (Rijns 1993). It is in near-permanent suspension and, therefore, can be transported through the stream without significant deposition (Sukhodolov et al. 2011). The discharge of this polluted silt and organic materials depends on the rate with which these particles become available from the catchment’s area and not on the transport capacity of the flow. An annual erosion of Lithuanian soils is 0.84-1.43 mm/year. (Vaičys et al., 1998) Thus 4.83 $10^6$ t/year of soil particles is lost in Lithuanian territory of the Nemunas catchment, and some part of it can be washed into the Nemunas river. This part is transported by the Nemunas River and its tributaries directly into Curonian Lagoon and has markedly negative effect on the environment here.

Oxidation of the organic material, brought to the rivers as wash load, reduces the amount of dissolved oxygen in quite a long reach of a river or a lake. The annual water runoff of the Nemunas approaches 22.1 $10^6$ m$^3$, and the total sediment output is up to 600-700 thousand t. (Pustelnikovas and Gulbinskas 2002) Due to significant pollution the River Nemunas has been identified as a hotspot in the Baltic Sea basin (Jokšas et al. 2005). The total annual dissolved inorganic N and phosphorus (PO$_4$ –P) discharge from the Nemunas catchment into the Curonian Lagoon ranged between 1620 and 4270 tons and about 636–969 tons per year, accordingly. Finally, a part of this load is transported into the Baltic Sea. As a result, this markedly increases the eutrophication here; therefore retention of this suspended organic material in the catchment’s area is very desirable.

Significant retention effect of the wash load and fine polluted suspended sediments was found in grassed floodplains of many rivers during the floods when the water at lower sites overflows their banks and the floodplain meadows are periodically inundated (Pierce 2009). For example, due to this phenomenon only approximately 1/3 of the sediment transported by the river Rhine reaches the North Sea. The rest sediment is deposited on the floodplains (Middelkoop & van Haselen 1999). It was estimated that sediment retention and nitrogen removal in these floodplains mainly depended on water flow retention time and flow conditions (Kothyari et al. 2009). Significant effect of suspended sediments retention on the deposition of fine particles has been also found in the Nemunas floodplains (Vaikasas & Rimkus 2003; Vaikasas & Dumbrauska 2010).

Thus, the sedimentation and pollutant retention process on the Nemunas floodplains is very important for both soil fertilization and water quality improvement here, and particularly in the Curonian Lagoon and the Baltic Sea. This is the reason why deposition and retention of wash load and its quantitative assessment was the main aim of this calculation.
Method of Investigations

The accurate assess of sediment transport, deposition and retention was necessary to adequately estimate the river’s floodplains impact on the water quality in the Curonian Lagoon. For this purpose an especially developed mathematical model has been employed for modeling of sediment dynamics and deposition in flooded meadows of the Nemunas (Rimkus et al. 2007; Rimkus & Vaikasas 2010). The already known models (MIKE 11 or MIKE 21) could not be applied, as they calculate only the movement of particles in the sandy riverbeds and are not suitable for grass-covered areas, where the suspended sediment deposition is several times greater (Boogerd et al. 2001; ). Therefore, the special investigations of sediment deposition have been performed during the floods in the Nemunas delta and in the flooded meadows of the river Nevėžis. Consequently, the following formulae have been developed:

\[
D = k_{cor} w \bar{C} / F, \tag{1}
\]

\[
F = \frac{\bar{C}}{C_a} = \left( \frac{a}{h-a} \right)^{z} \int_{h/2}^{h} (h-y)^{z} v_y dy + \int_{h/2}^{h} \exp(-4z(y/h-0.5))v_y dy \int_{0}^{h} v_y dy \frac{1}{y}, \tag{2}
\]

\[
z = \frac{w}{\beta k u_s}, \tag{3}
\]

where \(D\) – sediment deposition rate per unit of the bottom area, \(k_{cor}\) – correction coefficient estimating the state of grasses, \(w\) – velocity of sediment particles’ fall, \(\bar{C}\) – depth-average suspended sediment concentration, \(C_a\) – sediment concentration at the surface of grass layer, \(a = 0.3 h_r\), \(h_r\) – thickness of grass layer, \(h\) – water depth, \(v_y\) – flow velocity at the distance \(y\) from the bottom, \(\beta = 0.6, k = 0.4\) – van Karman number for estimation of open flow turbulence, \(u_s = \sqrt{\tau_u / \rho}\) - shear velocity at the surface of grass layer.

Some difficulties occur in choosing the formula for sediment deposition calculations in the main canal of the rivers. Most of the known formulas have been created according to the laboratory investigations for fine graded sand-bed rivers (Rijn 1993). Therefore, they are not valid for clay and silt particles calculation. The classical Zamarin’s formula created for fine and coarse particles has been chosen:

\[
C_{tr} = 0.022 \frac{v}{w_0} \sqrt{\frac{R_{iv}}{w}}, \tag{4}
\]

where \(C_{tr}\) – transportable sediment concentration, \(v\) – average flow velocity, \(R\) – hydraulic radius, \(i\) – kinetic energy gradient, \(w_0 = 0.002\) when \(w < 0.002\) m/s (for silt and clay) \(w_0 = w\) when \(w \geq 0.002\) m/s (for sand).

Calculation of suspended sediment deposition requires estimation of the distribution of stream velocities. Usually, the one-dimensional calculation methods are used for this purpose (MIKE 11 1995). However, they estimate only average flow velocity and total sediment discharge in cross-section. To estimate the sediment distribution across the valley, the river flow was divided into the strips with equal water discharges, for which the one-dimensional formulas were employed. Consequently, the model became quasi two-dimensional and, therefore, it can give more exact results. This enables us to calculate the sediment deposition in Nemunas basin, and to estimate more thoroughly the influence of floodplains on the river water quality (Fig. 1).
Figure 1. The map of the floodplain areas in the Nemunas river basin

During the floods the suspended sediment concentration data has been taken at the hydrometric post in Smalininkai. Investigations have been performed with 4 sediment fractions with particle diameters of 0.001, 0.002, 0.005 and 0.01 mm. The sedimentation rate that was identified in the river Nevėžis valley equals to the 0.7–0.8 kg/m$^2$ has been used for model calibration and verification.

**Results and Discussion**

The calculation results of fluvial sediment accumulation and their retention in the floodplains of the Nemunas catchment’s rivers during the floods is presented in Table 1. As it can be seen, 0.84-1.43 mm soil layer is washed from 426189 ha of the Nemunas river catchment’s area annually due to the water and the wind erosion. It has been calculated that in this way the catchment’s soil looses are 4.83 million m$^3$/year (Vaičys et al. 1998). Majority of these soil erosion products is retained in the riparian buffer strips and meadows of inner waters, covered by grass and only the fine sand particles dominate in the grain-size compositions of fluvial sediments transported by the Nemunas network rivers to the Curonian Lagoon. The composition of this sediment load is determined by the hydraulics of the rivers only. While the accumulation and retention of fine suspended sediments especially clay and silt is useful in different parts of the hydrographical network because it prevents the Nemunas river mouth and the Curonian Lagoon from being polluted with the soil erosion products rich in nutrients. Besides, this fine suspended sediment outflow works as fertilizers for the floodplain meadows and so prevents the Curonian Lagoon from getting silted intensively as well as eutrophication. A significant accumulation of mud has been calculated within 63 $10^6$ m length drainage channels, which are about 1.2 m width, within the 7560 ha of the total area. In totally there is accumulated about 82.6 $10^4$ t (59 $10^4$ m$^3$) or 10.9 kg/m$^2$/year of soil (Lamsodis et al., 2009). This makes even 23% of the all soil erosion products in the Nemunas catchment’s basin.

<table>
<thead>
<tr>
<th>Region of the floodplains or pools</th>
<th>Erosion</th>
<th>Accumulation</th>
<th>Area of erosion or accumulation, in 1000 ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nemunas catchment (2519531 ha)</td>
<td>4.83 $10^5$</td>
<td>100</td>
<td>2711</td>
</tr>
<tr>
<td>In the gullies and drain channels</td>
<td>8.26 $10^5$</td>
<td>23–15</td>
<td>7.56</td>
</tr>
<tr>
<td>In pond of Kaunas HPP</td>
<td>5.88 $10^5$</td>
<td>17–10</td>
<td>3.6</td>
</tr>
<tr>
<td>In floodplains below Kaunas HPP</td>
<td>4.69 $10^5$</td>
<td>14–9</td>
<td>67.0</td>
</tr>
<tr>
<td>In Delta of the Nemunas</td>
<td>4.58 $10^5$</td>
<td>13–8</td>
<td>66.2</td>
</tr>
<tr>
<td>In delta of the Jūra tributary</td>
<td>3.92 $10^5$</td>
<td>11–7</td>
<td>56.0</td>
</tr>
<tr>
<td>In onshore of the Baltic Sea</td>
<td>10.68 $10^5$</td>
<td>3–4</td>
<td>3.1</td>
</tr>
<tr>
<td>In the Curonian Lagoon</td>
<td>7.0 $10^5$</td>
<td>20</td>
<td>161.0</td>
</tr>
<tr>
<td>Totally in the Nemunas catchment’s area</td>
<td>4.83 $10^5$</td>
<td>100</td>
<td>3.56 $10^5$–5.61 $10^5$</td>
</tr>
</tbody>
</table>

The average sedimentation rate that was identified in the river Nevėžis valley equal to the 0.7 – 0.8 kg/m$^2$ was explored for the Nemunas and its major effluents floodplains below Kaunas hydropower plant (HPP). It was estimated that about 4.69 $10^5$ t/year sediments deposited there. It makes 9–14% of the annual river’s sediment transport rate. It is some peculiarity of the sediment transportation and retention in the higher part of the river Nemunas, because almost all this sediment amount is deposited in Kaunas HPP pond. It was estimated that on the average 5.88 $10^5$ t/year sediments were carried in and deposited there, which is 17% of the annual sediment load. Similar amounts of the suspended sediment retention have been estimated by mathematical modeling of the Nemunas Delta and its tributary the river Jura.
floodplains, i.e., about $4.58 \times 10^5$ and $3.92 \times 10^5$ t/year accordingly. Taking into account these calculation results and the related literature sources, it was found that about $7 \times 10^5$ t/year of suspended sediments carried by Nemunas deposited in the 161,000 ha Curonian Lagoon. As a result, it proves strong suspension ability of this natural sediment trap. The sediments being transported along the northern part of the Curonian Lagoon water area deposit in thin 1.5-2 mm/year layer or get carried by circulating flows into the non-flowing water area. The phenomenon of the permanent and unavoidable silt covering of lagoons has been described by Pustelnikovas (1998). According to him, the lagoon bed is covered by average 3.2 mm sediment layer annually. Thus, complex measures that have been described below might increase the overflow of Nemunas banks and silt retention, which would decrease the suspended sediment quantity entering the Curonian Lagoon and slow down the eutrophication here.

According to the related literature sources, meadows and grasslands in the river catchments retain sediment products eroded from the field (Harvey & Clifford 2009). It is a main reason that meadows and grassland cover a half of the total agricultural area in the many countries of the sustainable agro technique: in Austria it is 57%, in Holland and Belgium – 45%, in France – 39%, and in Switzerland it is even 80% (Jankowska-Huflejet 2006). To compare, in Poland the grassland area makes only about 13% of the total country area, which is 20% of the arable land. The arable land area in Lithuania makes about half of the total Nemunas catchment’s area. It suggests that the significant erosion is going here and some part of wash products transported by the Lithuanian rivers can be effectively retained in the floodplains only (Vaikasas & Rimkus 2003).

This fact is also proved by other countries’ experience too. Of course, a lot of fine particles of the eroded soil (wash products) are deposited and retained at the soil surface sinks, gullies and riparian buffer strips of the waterways as well as in the river valleys and are not transported into riverbeds (Pierce 2009.). As it was mentioned above, it is only less than 20% of the total suspended sediments that occur in to the river beds and can be transported in the Lithuanian rivers and further to the Curonian Lagoon. The remaining 80% are retained in the surface in floodplain meadows and waterbodies. Floodplain deposition is highly variable depending on frequency of flooding, distance to river channel, sediment load and texture, water velocity, and floodplain morphology. Therefore, it is still rather difficult to precisely estimate overall retention of the washed soil products in all investigated surface waters as well as its percentage distribution and deposits in different parts of the hydrographic network. It is because the sedimentation and the retention of fine suspended particles in the hydrographic network is still the subject of interest of further investigations. (Boogerd et al., 2001) However, it directly influences the amount of biogenic material and pollutants being transported to the Curonian Lagoon. Similar effect was found in the Ringkobing Fjord in Denmark, where the Skjern River transported 5,500 tons of nitrates, 100 tons of phosphates, 2,800 tons of ochre and 30,000 tons of silt, sand and gravel in suspension annually (The Danish Ministry 1999).

As the calculations show, the Nemunas carries only about $0.7 \times 10^6$ t. of sediments into the Curonian Lagoon annually. However, about 95% of it is sand (Vaikasas 2001, Rimkus and Vaikasas, 2012). During over bank flooding the water velocities are decreased resulting in sand particles deposition near the river channel thus developing natural levees. Finer silt and clay particles are transported further into the floodplain representing silt and clay deposits as flows retreat.

Thus, the deposited sediments are distributed unevenly in the valley: sand particles are deposited on the levees and in the nearest 100 m width sand bar (on average it is 1 kg/m²/year sediments). Further there are deposited smaller and smaller sediments until the fine clay particles. An average sediment quantity being deposited into the Nemunas Delta floodplains is about 0.5–0.7 kg/m²/year. The deposit also depends on the inflow water discharge; therefore it is very effective for the increase of sediment deposition to increase the floodwater overflow into the Delta via the deepening of riparian depressions. However, this overflow into the valley depends on riverbank relief and thus cannot be effective everywhere. The best versions can be estimated on the basis of the mathematical modeling. For the Nemunas delta this best case was when it was performed as the outflow canal track in the old river bed lake, from which the floodwater flow was direct into a valley, where significant part of fine sediment were deposited and retained (Rimkus & Vaikasas 2012). The possibility to deepen the riverbank depressions can be restricted by the demand to have summer flood prevention. As a result, from the environment point of view the impact of the artificially strengthened summer polders should be estimated in a complex way: usually relatively low embankments of summer polders do not have significant effect on the accumulation process of the suspended sediments in the floodplain. (Lukianas et al., 2006)

The Nemunas Delta valley flooding and the sediment deposition process for 1950-1991 have been modeled. The calculation results are plotted in Fig. 2. During the large floods the sediment deposition was also large. It was absent when the small floods did not overflow into the valley.
It was found that the flooded water left up to 0.1 - 2.25 mln. t. sediments in this part of the Nemunas Delta area. These sediments were deposited within 5200 ha of floodplain. On average it makes 43 kg/m² of the deposited silt, clay, and sand. However, it makes only 3.2 cm (or 0.8 mm/m²/year) deposit layer. From the point of view of relief formation, it is not much, but in the Curonian Lagoon water turbidity and biogenic water pollution is significantly reduced (Lamsodis and Vaikasas 2005).

On the basis of the mathematical modeling, it was established that when water flow was not large (water discharge 650–1200 m³/s, which are most frequent) the sediment deposition is proportional to the floodplain water discharge (Rimkus et al. 2007). When water flow rate is increasing, the clay particle sedimentation increment is a little bit less. It is due to their low sedimentation velocity as they do not have enough time to be settled all in floodplain and some of them are transported to the riverbed again. The sediment deposition in the floodplain area in time unit depends on the flood duration and particle sedimentation velocity, and does not depend on the momentary flood water discharge. Increment of flow velocity could decrease the sediment deposition in grasses only, if they were laid by very strong flow, what usually does not occur in floodplains. Thus, much more fine sediments are deposited during moderate floods due to the increased flooded area and the flood duration increment, and an effective discharge must be investigated. (Doyle et al., 2005)

As it was mentioned above, a very effective measure to retain silt is grass. The field measurement of 2005-2007 of the flooded valley of the river Nevežis showed that about 0.6-0.7 kg/m² silt could be deposited in the river valley grass annually (Pukštas and Vaikasas. 2005). In the whole Nemunas lower reaches (till Kaunas HPP) floodplains including the valleys of its greatest influents – the Neris, the Nevežis, the Dubysa, the Jūra and the Minija – there can be deposited about 4.7 $10^5$ t of sediments, which makes 9-14% of the Nemunas annual sediment load. This also has a rather significant effect on the sediment accumulation process in floodplain. Therefore, river valleys should be preserved and good condition both of the grass vegetation and the flooded grasslands should be formed.

Conclusions

It was estimated that in the Lithuanian part of the river Nemunas catchment with area of 2719530 ha, the average erosion of soil reached 4.8 $10^6$ t/year. Some part of this amount is retained in grassed catchment’s meadows. The rest washed sediment particles, rich with biogenic materials, are brought to the rivers and can be further transported to the Curonian Lagoon and even to the Baltic Sea.

The Nemunas river brings and partly settles there 0.1-0.7 mln. t/year of sediments go to the Curonian Lagoon. It makes about 20% of sediments brought by the river to the delta.

In small rivers and ditches, it is settled the considerable part, i.e., 15-23% of their entire amount getting in the river beds. It shows that the sediment retention and anti-erosion means are particularly effective in the upper reaches of rivers.

In the floodplains of the Nemunas lower reach (below Kaunas HPP) and in its tributaries (the Neris, the Nevežis, the Dubysa, the Jura and the Minija) are deposited and retained still about 4.7 $10^5$ t/year or 9-14% of all sediments getting in the rivers. The rest part is transported to the Nemunas delta.
References


Prof. habil. Dr. Saulius VAIKASAS, principle researcher at Water Resources Engineering Institute, Faculty of Water and Land Management, Aleksandras Stulginskis University. Research interests – investigations and modelling of flood currents and riverbed processes. Address: Parko str. 6, LT–58102 Vilainiai, Kėdainiai distr., Lithuania. Phone: (8-614) 35311. E-mail: s.vaikasas@delfi.lt
Appraisal of Small-leaf Linden (Tilia cordata Mill.) Growth Conditions near the Major Arterial Streets in Alytus City

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1Aleksandras Stulginskis University, Lithuania
2Kaunas Botanical Garden of Vytautas Magnus University, Lithuania

Abstract

The predominant variety among the town greenery in Lithuania is small-leaf linden (Tilia cordata Mill.). In order to assess its growth conditions in the urbanized environment, the research (2009–2012) was done in Alytus city as a part of activities designed to preserve as well as to plant new trees as an aesthetic, ecological, historically and culturally significant element of the local landscape.

Soil samples were taken from the topsoil (0-20 cm) and the chemical analyses were carried out by the appropriate conventional methods at the Agrochemical Research Laboratory of the Lithuanian Research Centre for Agriculture and Forestry. The 5 grade scale in relation to signs of damage has been applied for tree condition assessment.

The investigations revealed not so favourable soil conditions for the small-leaf linden trees near the major arterial streets in Alytus city. Although no risk of soil chemical pollution with Cl and Na was determined, the soil was found to contain too small quantities of such important nutrients as K and P. Besides, pH here is above 7, and this alkaline environment might complicate the uptake of these essential macronutrients by the plants.

It was found that the greatest negative impact on the state of small leaf linden was due to physiological damages (defoliation, discoloration, leaf necrosis, dry branches) and biotic factors: fungal diseases (sooty mould fungi Cladosporium herbarum, Leptosphaeria fumago), leaf spots agents Apiognomonia errabunda, Mycocphaeuae illageastrana and pests (Caliooa annulipes, Erysiphyes tilia-nervals, Eucalipterus tiliae, Schizotetranthus tilia-tum).

Key words: Town greeneries, soil quality, growth conditions.

Introduction

The green zones and buildings are the most important and visible elements in space of urbanized territories (cities, towns and conurbations). It is certainly well known that urban greenery may provide us with numerous environmental, economic and social benefits and contribute tremendously to the health and welfare of everyone who lives and works in the urban environment. As concerns grow about the quality of the urbanized areas in many towns and cities throughout the world, the importance of protecting and expanding of urban greeneneries can only increase. Thus, the permanent development of the system of urban greeneneries is always very important both from the point of view of optimization of urbanized environment and preservation of particular area natural values (Priaistienė, 2003; Chakre, 2006; Iqbal et al., 2008; Jutras et al., 2010; Nekrošienė and Kučinskienė, 2011; Žeimavičius et al., 2011).

In retail districts, visitors perceive the streetscape canopy to be an integral amenity of the city’s shopping environment and well-planned canopy-covered streets are highly appreciated (Wolf, 2004). Yet, urban landscapes are environmentally detrimental to the biology of trees (Percival, 2005). Frequently, street trees must cope with severe environmental conditions. Identification of factors that modulate their survival and growth is a key process for successful management (Jutras et al., 2010).

Plant supply with mineral nutrients, which functions can not be replaced by other chemical elements, is an important factor for normal plant growth and development. In the boreo-nemoral zone street trees are subjected by many negative factors, int. al., imbalanced plant supply with nutrients, as well as de-icing salt accumulation in greenery soil (Cekstere et al., 2010). The inadequate supply with biogenous elements can cause disturbances in different plant physiological processes, decreases tree tolerance to other unfavourable factors (Cekstere and Osvalde, 2010).

Soil water resources in the street planting pits are generally reduced and severe physiological problems then develop: impaired respiration, protein synthesis, secondary carbohydrate metabolism, disintegration of leaf structure, and reduced growth of stems and twigs, followed by death of terminal buds and branches and by production of small and chlorotic leaves (Jutras et al., 2010). Urban soil conditions may also be adverse for adequate tree development. One of the critical barriers is the complexity of the urban infrastructure and the competition for space below ground. Ideally, trees should be planted for the long term so that they can grow to maturity and deliver their benefits. This means that they need a sufficient soil volume to grow in (Kelly, 2011, Gull et al., 2012).

Although estimates vary, life spans of trees in urbanized areas are often significantly less if compared to trees in rural areas or natural habits (Cregg and Dix, 2001). Therefore, plants origin is very important as well. The priority should be given to plants only completely resistant to weather conditions (Januškevičius and Navys, 2012).

The objectives of the research were: (1) to evaluate soil quality factors that are important for the plant growth near the major arterial streets; (2) to assess the vitality of small-leaf linden in the investigation sites in relation to fungal disease and pests.

Material and methods

Alytus, the sixth largest Lithuanian city is situated along the both banks of the river Nemunas at the crossing of the main roads linking Kaunas with Grodno (Belarus) and Vilnius with Lazdijai (Lithuanian-Polish border town). In 2009–2012 the state of small-leaf linden (Tilia cordata Mill.) growth conditions has been assessed near by four major Alytus city arterial streets.
From the geographical point of view, soils within the boundaries of communities are defined as urban soils. From the pedological point of view, these soils are severely changed by man but not primarily by cultivation practices. According to Lithuanian National soil classification system, we have defined soils in Alytus city near the major arterial streets as the Urbic Anthrosols (Eidukevičienė and Vasiljevičius, 2001).

The composite soil samples were collected from the upper 0-20 cm layers (humic horizon) in 3 replicates by soil auger using the linear sampling method. For the laboratory analysis soil samples were air-dried, sieved through 2 mm sieve, homogenised and stored according standard ISO 11464:1994. Soil pH was measured in 1M KCl suspension (ISO 10390:1994); Ca, Mg, K and Na estimated in BaCl₂ extract (ISO 11260:1994); P determined by CAL method; Cl⁻ in H₂O 1:5 extract by titrimetric method.

The pathological condition of small-leaf linden (Tilia cordata Mill.) was assessed every year in August using the methodology by A. Brukas (1988), M. Vaičys et al. (1989) and A. Juodvalkis and A. Vasiljevičius (2002). The 5 grade scale in relation to signs of damage has been applied for tree condition assessment (Table 1).

### Table 1. Tree condition assessment scale

<table>
<thead>
<tr>
<th>Degree of tree condition</th>
<th>Signs of damage</th>
<th>Grades</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relatively healthy</td>
<td>Leaf or trunk defoliation up to 10%, crown characteristic of the species, trees without signs of weakening.</td>
<td>1</td>
</tr>
<tr>
<td>Weakened</td>
<td>Trees with slightly open crown; reduced increment; up to 11-30% leaves, trunks and branches are damaged (defoliation, discoloration, diseases, pest).</td>
<td>2</td>
</tr>
<tr>
<td>Weak</td>
<td>Open crown; highly reduced increment or its absence; 31-60% of leaves, branches or trunks are damaged or dead.</td>
<td>3</td>
</tr>
<tr>
<td>Dying</td>
<td>Crown is extremely open; 61-80% of leaves, branches or trunks are damaged.</td>
<td>4</td>
</tr>
<tr>
<td>Dead leaves, fresh deadwood</td>
<td>81-100% of leaves, branches or trunks are damaged. Recently dead trees.</td>
<td>5</td>
</tr>
</tbody>
</table>

Mean damage grade was calculated for the studied trees according to the formulae (Juodvalkis and Vasiljevičius, 2002):

\[
V = \frac{\sum (n \cdot b)}{N}
\]

where: 
- \( V \) – mean damage grade;
- \( \sum (n \cdot b) \) – number of plants damaged to the same grade as well as product sum of it and the grade;
- \( N \) – number of checked plants.

Pathogens were identified according to disease symptoms, cultural and morphological traits of distinguished microorganisms, based on the descriptors (Sinclair and Lyon, 2005; Butin, 2011). Pests were described according to (Pileckis et al., 1968; Hartmann et al., 2005).

The leaf samples of small-leaf linden were collected in four major arterial streets in order to examine possible negative affecting of de-icing salts (KCl and NaCl). A park – Jaunimo garden – was chosen as control variant in order to assay the background element concentration levels in the leaves of small-leaf linden trees. The chemical analyses of the leaves were carried out by standard methods in the accredited Agrochemical Research Laboratory of Lithuanian Research Centre for Agriculture and Forestry. Statistical calculations were made using Excel (90.6926SP-3) program.

### Results and discussion

The results of soil quality factors are summarized in Table 2. Analysis of soil pH range, which is one of the most important factors for the availability of nutrients for the plants, showed that soil was rather alkaline near the major arterial streets in Alytus city. In general, soil is slightly alkaline (pH 7.2-7.6) but in case of Pulko street it might be attributed to moderately alkaline. It is well known, that at higher pH levels such as 7.8 and above, nutrients such as calcium and magnesium are more available for plant uptake.

### Table 2. Quality factors of the soils near by major arterial streets in Alytus city, 2009-2012

<table>
<thead>
<tr>
<th>Soil sampling site</th>
<th>pH</th>
<th>P mg kg⁻¹</th>
<th>K mg kg⁻¹</th>
<th>Ca mg kg⁻¹</th>
<th>Mg mg kg⁻¹</th>
<th>Na mg kg⁻¹</th>
<th>Cl⁻ mg kg⁻¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Juozapavičius street</td>
<td>7.47±0.06</td>
<td>80.92±8.14</td>
<td>88.73±9.82</td>
<td>2955.95±201.90</td>
<td>250.66±12.49</td>
<td>75.48±40.64</td>
<td>8.87±2.50</td>
</tr>
<tr>
<td>Kauno street</td>
<td>7.65±0.21</td>
<td>93.04±7.07</td>
<td>97.16±1.38</td>
<td>1986.01±118.67</td>
<td>196.99±21.16</td>
<td>71.95±2.93</td>
<td>7.70±2.75</td>
</tr>
<tr>
<td>Naujoji street</td>
<td>7.20±0.45</td>
<td>69.93±14.12</td>
<td>88.36±19.90</td>
<td>2750.48±519.77</td>
<td>204.04±19.77</td>
<td>85.98±5.53</td>
<td>9.50±1.04</td>
</tr>
<tr>
<td>Pulko street</td>
<td>8.13±0.30</td>
<td>57.61±10.21</td>
<td>63.14±29.57</td>
<td>1436.97±325.21</td>
<td>255.05±91.92</td>
<td>76.55±4.87</td>
<td>7.10±1.80</td>
</tr>
</tbody>
</table>

However, other nutrients such as iron, copper, zinc, manganese, and phosphorous are much less available in the alkaline environment. Even if soils contain adequate amounts of mineral Fe, but as soil pH rises above 7.0, Fe changes to an insoluble form that many plants have difficulty taking up. Affected leaves turn to a yellowish color while leaf...
observations in order to get a more sufficient data-based argument for any connections between application of the de-
and Pulko streets in 2011 as compared to 2009. Such a diverse state might be related to the differing intensity in the
Cl and Na distribution. The increased concentrations of these elements were found in Kauno and Naujoji streets in 2011
greenery during 2009 and 2011
Table 3.
<table>
<thead>
<tr>
<th>Site</th>
<th>Year</th>
<th>N</th>
<th>P</th>
<th>K</th>
<th>Ca</th>
<th>Mg</th>
<th>Na</th>
<th>Cl</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Juozapavicius street</td>
<td>2009</td>
<td>2.54</td>
<td>0.35</td>
<td>1.29</td>
<td>2.20</td>
<td>0.18</td>
<td>0.12</td>
<td>0.55</td>
</tr>
<tr>
<td></td>
<td>2011</td>
<td>2.32</td>
<td>0.26</td>
<td>1.35</td>
<td>2.42</td>
<td>0.19</td>
<td>0.073</td>
<td>0.28</td>
</tr>
<tr>
<td>Kauno street</td>
<td>2009</td>
<td>2.60</td>
<td>0.21</td>
<td>1.41</td>
<td>2.16</td>
<td>0.37</td>
<td>0.02</td>
<td>0.40</td>
</tr>
<tr>
<td></td>
<td>2011</td>
<td>2.52</td>
<td>0.20</td>
<td>1.52</td>
<td>2.15</td>
<td>0.23</td>
<td>0.03</td>
<td>0.70</td>
</tr>
<tr>
<td>Naujoji street</td>
<td>2009</td>
<td>2.07</td>
<td>0.23</td>
<td>0.87</td>
<td>2.46</td>
<td>0.34</td>
<td>0.03</td>
<td>0.29</td>
</tr>
<tr>
<td></td>
<td>2011</td>
<td>1.99</td>
<td>0.19</td>
<td>1.32</td>
<td>2.45</td>
<td>0.20</td>
<td>0.049</td>
<td>0.71</td>
</tr>
<tr>
<td>Pulko street</td>
<td>2009</td>
<td>2.43</td>
<td>0.25</td>
<td>1.57</td>
<td>2.04</td>
<td>0.17</td>
<td>0.05</td>
<td>0.41</td>
</tr>
<tr>
<td></td>
<td>2011</td>
<td>2.34</td>
<td>0.26</td>
<td>1.59</td>
<td>2.05</td>
<td>0.22</td>
<td>0.049</td>
<td>0.35</td>
</tr>
<tr>
<td>Control (Youth garden)</td>
<td>2011</td>
<td>2.09</td>
<td>0.21</td>
<td>1.34</td>
<td>2.88</td>
<td>0.27</td>
<td>0.040</td>
<td>0.10</td>
</tr>
</tbody>
</table>

In general, analysis of the mean damage grade of Small-leaf Linden (Table 4) showed the tendency of different
origin damage decrease in 2012 as compared to previous years (2009–2011).

Table 4. The mean damage grade of Small-leaf Linden (Tilia cordata Mill.) in Alytus city major arterial streets greenery, 2009–2012
<table>
<thead>
<tr>
<th>Site</th>
<th>Year</th>
<th>Defoliation and discoloration</th>
<th>Leaf necrosis</th>
<th>Dry branches</th>
<th>Damage of stems</th>
<th>Diseases</th>
<th>Pests</th>
</tr>
</thead>
<tbody>
<tr>
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<td>1.93±0.07</td>
<td>1</td>
<td>1.93±0.07</td>
<td>1.47±0.08</td>
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<td>1.47±0.08</td>
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<td>3.52±0.08</td>
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<td>1.14±0.06</td>
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<td>1.23±0.13</td>
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<td>Kauno street</td>
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<td>1.01±0.03</td>
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<td>Naujoji street</td>
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<td>1.00±0.02</td>
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<td></td>
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</tr>
<tr>
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<td>2.43±0.08</td>
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<td>1</td>
<td>3.82±0.09</td>
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<tr>
<td></td>
<td>2012</td>
<td>1.16±0.10</td>
<td>1.04±0.11</td>
<td>1.24±0.10</td>
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</table>

In Alytus city, where light-textured sandy soils dominate, a deficiency of moisture is usual problem leading to
the untimely defoliation of the trees. Therefore, it is likely that the longer dry period than usual in 2009 was
unfavourable for the Small-leaf Linden – the defoliation and discoloration grade was from 1.26±0.27 up till 1.93±0.07.
A large part of old trees were cut off during the reconstruction of A. Juozapavičiaus and Naujoji streets in 2011–2012. Therefore, the rate of mechanically damaged (i.e., by cars and lawn mowers) trees stems decreased from 1.47±0.08 (Juozapavičiaus street) up till 1.23±0.13. In particular, up to 2-4 times lower damage by fungal diseases and pests was observed in 2012.

One of the most widespread diseases among the Small-leaf Linden variety is leaf spots disease (agent Mycosphaerella millegrana (Cooke) J. Schröt.). The data shows (Table 5) the particular high presence of this disease in 2010 while in 2011 more widespread was another leaf spots disease – agent Apiognomonia errabunda (Roberge ex Desm.) Höhn. The study revealed that intensive damage in 2011 was done for the Small-leaf Linden by the pest Caliroa annulipes.

### Table 5. Fungous disease / pests of Small-leaf Linden (Tilia cordata Mill.) in Alytus city major arterial streets greenery, 2009–2012

<table>
<thead>
<tr>
<th>Site</th>
<th>Year</th>
<th>Mean damage grade</th>
<th>Disease agent / pest</th>
<th>Site</th>
<th>Year</th>
<th>Mean damage grade</th>
<th>Disease agent / pest</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Juozapavičiaus street</td>
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<td>2±0.07</td>
<td>Euplomeris tiliae and Cladosporium herbarum, Leptothyphium fumago</td>
<td>Kauno street</td>
<td>2009</td>
<td>1</td>
<td>Mycosphaerella millegrana</td>
</tr>
<tr>
<td></td>
<td>2010</td>
<td>1.09±0.09</td>
<td></td>
<td></td>
<td>2010</td>
<td>1.05±0.24</td>
<td>Apiognomonia errabunda</td>
</tr>
<tr>
<td></td>
<td>2011</td>
<td>3.26±0.08</td>
<td></td>
<td></td>
<td>2011</td>
<td>4.83±0.23</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2009</td>
<td>1</td>
<td>Mycosphaerella millegrana</td>
<td></td>
<td>2009</td>
<td>1</td>
<td>Euplomeris tiliae and Cladosporium herbarum, Leptothyphium fumago</td>
</tr>
<tr>
<td></td>
<td>2010</td>
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<td>2010</td>
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<td>Euplomeris tiliae and Cladosporium herbarum, Leptothyphium fumago</td>
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<td>Schizotetranychus tiliarum</td>
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<td>1.85±0.11</td>
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</table>

Since a Small-leaf Linden (Tilia cordata Mill.) is one of the most popular native tree species in Lithuania, consequently it has become susceptible to a large variety of fungal diseases and pests. Research results by other scientists also suggest that the intolerance of Small-leaf Linden photosynthetic apparatus to urban environment conditions have resulted in a decreased resistance of this species to a number of pests and fungal diseases (Swozyna et al. 2010). However, another lime tree species – Tilia x vulgaris H., known also as Tilia x europaea L., it is more popular tree used for urban landscaping in many Central, Northern and Eastern European countries instead of Tilia cordata Mill.

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(Cekstere and Osvalde, 2013). Therefore, while planning new greenery planting in Lithuania it also should be taken into consideration a possibility to use other species than Small-leaf Linden (*Tilia cordata* Mill.) in order to improve the vitality of trees in urban environment.

**Conclusions**

The investigations revealed not so favourable soil conditions for the small-leaf linden trees near the major arterial streets in Alytus city. Although no risk of soil chemical pollution with Cl and Na was determined, the soil was found to contain too small quantities of such important nutrients as K and P. Besides, pH here is above 7, and this alkaline environment might complicate the uptake of essential macronutrients by the plants. The greatest negative impact on the state of small leaf linden was due to physiological damages (defoliation, discoloration, leaf necrosis, dry branches) and biotic factors: fungal diseases (sooty mould fungi: *Cladosporium herbarum*, *Leptosphyrium fungago*, leaf spots agents *Apiognomonia errabunda*, *Mycosphaerella citricarpa* and pests (*Caliroa annulipes*, *Eryophyes tilia-nervalis*, *Eucalyptus tiliae*, *Schizotetranychus tilharum*).

**References**

Impact of Discrete New Real Estate Developments on the Spatial Properties of Arable Land

Piret Veeroja, Eddy Heil, Mari Maltis, Siim Maasikamäe

Estonian University of Life Sciences

Abstract

Real estate development and the formation of new residential areas take place not only as the enlargement of existing settlements which often occur in the form of urban sprawl, but also in the sporadic development of new residential areas in the form of small scattered areas. Such areas are sometimes discrete and separated from other built up areas. The allocation of new development areas, including discrete areas, on arable land will often have negative impacts on the spatial properties of those arable land parcels. The aim of the study is to assess the impacts of new discrete real estate developments on the spatial properties of arable land parcels in the sparsely populated rural areas. Tartu County in Estonia was the study area. The study was built up on GIS analysis; the main data sources were various digital maps. The results of the study showed that many new discrete residential area developments (79 per cent) had an impact on the spatial properties of arable land. They were located fully or partially on arable land. The magnitude of the negative impact of the new development areas on the spatial properties of arable land parcels was medium in 22 per cent of cases and large in 27 per cent of the cases, if the arable land parcels were affected by discrete developments. The ratio of arable land in the area of new discrete residential developments was on average 49.5 per cent.

Key words: discrete residential areas, real estate development, spatial properties of arable land, urban sprawl.

Introduction

The decrease of arable land area per capita is a worldwide problem. N. Alexandratos and J. Bruinsma (2012, pp. 108) pointed out that worldwide, the area of arable land per capita in 1960 was 0.44 hectare; in 2010 this figure was 0.23 hectare; the projection for the 2050 is 0.181 hectare. There are more similar prognoses and projections made, for example, by J. Bruinsma (2011), B. R. Döös (2002) and FAO (2002).

One of the reasons for the decrease in arable land is urban sprawl (Brueckner, 2000; EEA, 2006; Matlovič and Sedláková, 2007). The conversion of arable land for other purposes occurs mainly in areas surrounding cities and close to other densely populated areas.

Different aspects of urban sprawl and developments of new residential areas have been highlighted in several studies. Some have investigated causes of urban sprawl, e.g. social causes (see Brueckner, 2000; EEA, 2006; Matlovič and Sedláková, 2007; Thomas, 2011), political causes (see EEA, 2006; Thomas, 2011), technological causes (see Jetzkowitz et al., 2007; Matlovič and Sedláková, 2007) and economical causes (see Brueckner, 2000; EEA, 2006; Matlovič and Sedláková, 2007; Thomas, 2011). Others have examined its consequences, e.g. social consequences (see EEA, 2006; Matlovič and Sedláková, 2007), environmental consequences (see Brueckner, 2000; Deng et al., 2011; EEA, 2006; Matlovič and Sedláková, 2007; Setälä et al., 2013, Thomas, 2011) and economic consequences (see EEA, 2006; Matlovič and Sedláková, 2007; Zasada et al., 2012; Thomas, 2011). Third group of authors offer management tools for urban sprawl (see Blair and Wellman, 2012; Brueckner, 2000; EEA, 2006; Mukupa 2011).

The above short review of different studies shows clearly the complex and many-sided character of urban sprawl. Urban sprawl has been considered as uncontrolled development; its impact on the land use conditions for agriculture has been studied by many researchers: Hewitt and Escobar (2011), Spilková and Šefrina (2011), Zasada et al. (2011), Zasada et al. (2012) and Tan et al. (2005) are just a few examples. Uncontrolled real estate development is a problem for Estonia, too (Maasikamäe et al., 2011, Roose et al 2013). It is also necessary to note that the conversion of arable land into non-agricultural land takes place not only as the expansion of existing settlements and as urban sprawl.

The aim of this study is to assess the impact of new real estate developments on the spatial properties of arable land parcels in sparsely populated rural areas. The study focused on the discretely located new residential plot developments. The term ‘discrete’ emphasises the fact that some development areas are located separately from existing settlements and at random. Such discrete development areas are usually not large: sometimes fewer than 10 new residential sites have been planned. A systematic study of discrete real estate developments in a particular area (e.g. county) will contribute a better understanding of the extent and magnitude of the impacts of the phenomenon on the spatial properties, of arable land parcels. An arable land parcel is understood as an undivided and continuous area of arable land, not split by roads, ditches or other objects. The shape and compactness of the arable land parcels are the main studied spatial properties. The study was carried out based on the example of Tartu County in Estonia.

The results of the study indicated that discrete real estate developments can have negative impacts on the spatial properties of arable land parcels. The current study is the continuation of that by Maasikamäe et al. (2011) which established the groundwork for systematic investigation of the impact of uncontrolled real estate development on land use conditions in agriculture.

Study area, materials and methods

The study area is Tartu County, which is located in South-East Estonia (see Figure 1). According to Statistics Estonia (http://www.stat.ee/ppe-tartu-maakond) the county’s area is 2992.74 km² and population is 150 139 inhabitants (by date 31.05.2013). It is the sixth largest county in area and has the third largest population per county in Estonia. The centrally-located county center is Tartu, the second largest city in Estonia. Tartu is the main urban center for southeast Estonia and is an internationally known university city. The county also includes two smaller towns (Elva and Kallaste)
and 19 rural municipalities. Our study investigated real estate developments only in the rural municipalities. Aside from Tartu, Elva and Kallaste, we excluded from the study all real estate developments in the densely populated areas such as boroughs and small towns.

Figure 1. Estonian counties and location of the study area (Tartu County)

The study was carried out mainly in the GIS environment (Arc GIS and Quantum GIS) using various digital maps as the main data sources. The digital base map from 2009 was used for determining the acreage of arable land areas. Although there is a newer map available, an older one was used because some of the former arable land has been changed to other land types, e.g. yards, on the recent maps. The second important data source was the map of cadastral units (dated May 2012). Orthophotos and historical maps from the Estonian Land Board geo-portal (xgis.maaamet.ww/XGIS/XGis) were the third data source.

The first task was the formation of the map of areas (polygons in GIS) in which at least four residential plots were located side-by-side in a group, referred to as study units below. The choice of a minimum of four side-by-side plots as the lower limit for determination of a study unit was based on a preliminary study of new real estate developments. The principle of formation study units is presented in Figure 2. The second criteria for including the plot was the area of plots. Plots larger than one hectare were not included, even if the intended use was residential land. The plots in new real estate development areas do not usually exceed 0.5 hectare, and are more commonly 0.1 to 0.2 hectare. Various GIS tools were implemented for formation of the first set of study units (total number 352 regions).

Figure 2. The formation of study units from the side-by-side residential plots: eight residential plots and street area (part A) are combined into a study unit (part B)

The second task of the study was visual inspection of the study units in the background of ortho-photo maps, to determine whether or not the study area is discrete. The different GIS overlay techniques and queries are not expedient for such a task because it is difficult to set clear selection criteria. Even though the results of visual inspection can contain some errors, it is a more flexible and reliable technique for such tasks. All study units with the following characteristics were excluded from the final set of units selected:

- The study unit was a group of summer cottages or summer houses; typically, such plots have buildings, with trees surrounding the buildings (see Figure 3, A);
- The study unit was part of an existing settlement (e.g. village centre) or a group of existing houses (see Figure 3, B and C);
- The unclear study units were excluded from further study.

Figure 3. Examples of excluded study units: dotted line is the boundary of a study unit (Source: Estonian Land Board: xgis.maaamet.ww/XGIS/XGis)
The final number of study units for investigation was 106. Two examples of typical study units are presented in Figure 4. Part A, Figure 4 shows a new real estate development area which is located on arable land without adjoining built-up areas. Part B illustrates real estate development areas adjoining existing residential plots.

![Figure 4. Examples of typical study units; dotted line is the boundary of study units (Source: Estonian Land Board: xgis.maaamet.ww/xGIS/XGis)](image)

Allocating a new residential area on an arable land parcel will change its spatial properties. The third task of the study was evaluation of the negative impacts of real estate development on arable land parcels. Two parameters were evaluated for this purpose: a) the type of change of spatial properties of the arable land parcels caused by the new residential real estate developments and b) the magnitude of the negative impacts of real estate developments on the use conditions (spatial properties) of arable land parcels. The following values (types of changes) were found for the first parameter:

- Real estate development split an arable land parcel into separate parts, resulting in at least two parcels of arable land instead of the initial single parcel.
- Real estate development area is wedged into the parcel of arable land;
- Real estate development area is located in the corner of the arable land parcel;
- Real estate development area is area is centered on the side of the arable land parcel, usually in parallel with a bigger road;
- Real estate development area overlaps two or more arable land parcels and impacts each arable land parcel that it overlaps differently;
- Large arable land parcels are planned for new residential areas; normally the area of residential developments was less than 10 ha, but in those cases it was about 30 ha or higher;
- Real estate development area covers, fully or partly, small parcels of arable land that are usually smaller than the development area itself;
- No arable land affected by real estate developments.

As stated above, the main study question was the impact of real estate developments on the shape and compactness of arable land parcels. In most cases, the impact of real estate development is negative: the compactness of arable land parcels was reduced and their shape worsened. The three-level gradations were used for the evaluation of the magnitude of possible negative impacts of the real estate developments on the land use conditions of arable land parcels. The grades (small, medium and large) were given as expert opinions by the visual evaluation of the impact of real estate developments on the arable land parcels. If the shape and compactness changed only slightly, then the possible negative impacts were graded as “small”; very remarkable changes were graded as “large”; moderate impact was graded respectively as “medium”.

Finally, the study units were analysed after their evaluation in the GIS environment. The intersection of study units and arable land parcels of Tartu County was implemented in ArcGIS environment in order to find the acreage of arable land for each investigated study unit.

**Results**

The main results of the study are presented in Tables 1 and 2. Table 1 shows that more than three quarters of the investigated study areas (84 out of 106 -79 %) were located at least partly on arable land; consequently they caused some changes in spatial properties of arable land parcels. Placing a new residential area in the corner or centred on the side of an arable land parcel is the most common (41 cases). By the ratio of the area under investigated developments those two groups makes only 26 per cent. The ratio of arable land in development area was more than 60 per cent for five types of developments (see last column in Table 1). The ratio of arable land in the development area was relatively low in cases where the real estate development areas overlapped two or more arable land parcels and where the real estate development areas fully or partly covered small parcels of arable land.
Table 1. *The distribution of new real estate development areas by the type of change of the spatial properties of the arable land parcels*

<table>
<thead>
<tr>
<th>The type of change of spatial properties of the arable land parcels caused by new development areas</th>
<th>No of cases</th>
<th>Percentage of the cases</th>
<th>Area under development (ha)</th>
<th>Area under development in per cents</th>
<th>Area of arable land in the development (ha)</th>
<th>Ratio of arable land in per cent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arable land parcel was split into separate parts</td>
<td>11</td>
<td>10</td>
<td>95.9</td>
<td>13</td>
<td>59.6</td>
<td>62.2</td>
</tr>
<tr>
<td>Development area wedged into the arable land parcel</td>
<td>11</td>
<td>10</td>
<td>48.5</td>
<td>6</td>
<td>39.8</td>
<td>82.2</td>
</tr>
<tr>
<td>Development area is in the corner of the arable land parcel</td>
<td>23</td>
<td>21</td>
<td>107.7</td>
<td>14</td>
<td>67.1</td>
<td>62.2</td>
</tr>
<tr>
<td>Development area is centered on the side of the arable land parcel</td>
<td>18</td>
<td>17</td>
<td>92.7</td>
<td>12</td>
<td>64.0</td>
<td>69.1</td>
</tr>
<tr>
<td>Real estate development area overlaps two or more arable land parcels</td>
<td>11</td>
<td>10</td>
<td>119.9</td>
<td>16</td>
<td>24.6</td>
<td>20.5</td>
</tr>
<tr>
<td>Large arable land parcels are planned for new residential areas</td>
<td>4</td>
<td>4</td>
<td>132.3</td>
<td>18</td>
<td>101.2</td>
<td>76.5</td>
</tr>
<tr>
<td>Real estate development area covers fully or partly small parcels of arable land</td>
<td>6</td>
<td>6</td>
<td>40.5</td>
<td>5</td>
<td>13.3</td>
<td>32.9</td>
</tr>
<tr>
<td>No arable land was found on the development area</td>
<td>22</td>
<td>21</td>
<td>108.50</td>
<td>15</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>106</strong></td>
<td><strong>100</strong></td>
<td><strong>746.0</strong></td>
<td><strong>100</strong></td>
<td><strong>369.6</strong></td>
<td><strong>49.5</strong></td>
</tr>
</tbody>
</table>

It is worth noting that the new development area was located totally on arable land in six cases. The ratio of arable land in development area was equal or more than 75 per cent in 41 cases and equal or more than 50 per cent in 59 cases. In other words: at least half the development area was on arable land in 56 per cent of investigated cases.

The magnitude of the impact of new development areas on the spatial properties of arable land parcels is presented in Table 2. The table contains data only in cases in which the spatial properties of arable land parcels worsened. There were four cases in which the new development area, located in the corner of arable land parcel, improved the spatial properties of those parcels; those cases are not reflected in Table 2. The table also does not contain data about three types of development areas that were presented in Table 1: a) large arable land parcels planned for new residential areas, b) real estate development area fully or partly covering small parcels of arable land, c) no arable land was found on the development area.

In this study were detected four cases in which large arable land parcels were planned for new residential areas. There were more than 100 residential plots planned in each study area. The primary result of large discrete development areas on the arable land is loss of this land for agriculture. The impact of such developments on the spatial properties of arable land parcels is sometimes missing because the arable land parcels no longer exist. Thus, this type of development was excluded from table 2.

It is also difficult to assess the impact of real estate development areas that fully or partly cover small parcels of arable land. The problem is somewhat similar to that of real estate developments on large arable land parcels. Namely, the small arable land parcels (1 or 2 hectares) are often fully developed as real estate, without arable space remaining. Additionally, those areas, of arable land which do remain are small. It is difficult to use contemporary machinery on an arable land parcel of less than two hectares. As a result, such areas frequently are not in active use or are even abandoned.

Table 2 shows that the impact of new development areas on the spatial properties of arable land parcels is large (16 cases) or medium (6 cases) if they split or wedge into an existing arable land parcel. In those two cases was the impact on arable land parcels small.

Table 2. *The magnitude of the negative impact of new development areas on the spatial properties of arable land parcels*

<table>
<thead>
<tr>
<th>The type of change of spatial properties of the arable land parcels caused by new development areas</th>
<th>Magnitude of negative impact</th>
<th>Total no of cases by types of impact</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Small</td>
<td>Medium</td>
</tr>
<tr>
<td></td>
<td>No of cases</td>
<td>Per cent of cases</td>
</tr>
<tr>
<td>Arable land parcel was split into separate parts</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Development area wedged into arable land parcel</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Development area is in the corner of the arable land parcel</td>
<td>13</td>
<td>68</td>
</tr>
<tr>
<td>Development area is centered on the side of the arable land parcel</td>
<td>15</td>
<td>83</td>
</tr>
<tr>
<td>Real estate development area overlaps two or more arable land parcels</td>
<td>8</td>
<td>73</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>36</strong></td>
<td><strong>51</strong></td>
</tr>
</tbody>
</table>
Allocation of a new development area into a corner or center it on the side of the arable land parcel had mainly (28 cases) a small impact on the spatial properties of those arable land parcels. Medium and large impact was detected in 7 and 2 cases, respectively, three times less than cases with small impact. A similar pattern of impact on spatial properties of arable land parcels characterises the real estate development areas that overlap two or more arable land parcels.

**Discussion**

The results of the study show that developments of new discrete residential areas are often planned on arable land; if implemented, such developments might worsen the spatial properties of arable land parcels. The study focuses only on the discrete developments of new residential areas. Other types of real estate developments (i.e. commercial or industrial) were not investigated. Developments that expanded existing settlements were also excluded. Therefore, the results of the study characterise only the impact of one type of discrete real estate development on arable land use conditions.

It is necessary to note that the distinction between discrete real estate development areas and the expansion of existing densely populated areas is sometimes problematic. It is not easy to set strict and quantifiable criteria for that purpose. The selection of areas for the study units was done mainly on the basis of expert opinions. However, the one clear criterion was the condition that each study unit should be surrounded by other than residential land use.

The visual assessment according to expert opinion of the impact of discrete real estate developments on the spatial properties of arable land parcels is somewhat problematic. One can say that the calculation of coefficients of compactness, for example, might be a more objective measure for that purpose. In some cases the change of coefficient of compactness will correspond well to the change of the use conditions of arable land parcels. However, sometimes the coefficient of compactness will improve (or be reduced) after the allocation of new development areas on the arable land parcel, while worsening land use conditions at the same time. It can happen, for example, if the new development area splits a large stretch of arable land parcel into parts. The separated parcels may be more compact compared to the initial parcel but the average size of parcels will be reduced. Our experience is that, compared to sole calculation of the coefficients of compactness, visual assessment of the impact of new development areas on the spatial properties of arable land parcels is more complex.

To better understand the results of the study, one important aspect should be kept in mind. The area of arable land for the study units was calculated by ArcGIS; a digital topographic map was the data source for that task. Nevertheless, in some cases it was obvious that the non-agricultural land indicated on the map (e.g. residential land) was formerly agricultural (arable) land. This problem is caused by a difference in legal status of the plot and the actual land use on the site. The examples in Figure 4 illustrate the problem: not all residential parcels include buildings. The area (or a part of it) has been interpreted in the mapping process as yard or other non-agricultural land if the aerial photos show buildings or other constructions. New aerial photos are usually taken every fourth year. We used the topographic digital map from 2009 in this study in order to have data about past areas of arable land. However, some initially arable land areas on that map had already been marked as non-agricultural land. In some cases it was obvious that the residential plot had been located on former arable land. Therefore, the actual area of arable land on the study units was initially bigger than detected by the GIS overlay analyses. One can say that the negative impact of discrete real estate developments on the arable land use conditions was underestimated rather than overestimated in this study.

Only one aspect of the discrete real estate developments has been investigated in this study; further, wider research in this field is needed. Future studies should not restrict the research to residential areas but should also include other types (commercial, industrial etc.) of discrete real estate developments. The second important question to be answered is the quality of life in the distinct groups of houses.

**Conclusion**

The results of the study showed that the discrete new residential areas developments have considerable impact on the spatial properties of arable land parcels. The main conclusions are as follows:

- The discrete developments of new residential areas occurred to a large extent on arable land. The ratio of arable land area in the investigated 106 developments was on average 49.5 per cent. Figuratively, it means that every second hectare for discrete real estate development is planned to be located on arable land.
The majority of discrete new residential areas developments (79 per cent of investigated cases) had some impact on the spatial properties (shape and compactness) of arable land parcels. This impact is usually negative – the land use conditions worsened.

The new development areas had small impact on the spatial properties of arable land parcels in 51 per cent of cases if the arable land parcels were affected by discrete developments. This impact was considered to be medium or large in 22 per cent and 27 per cent of cases, respectively.

References
Spatial Dispersion Analysis of Spring Flood Peak Discharge 1% Probability of the Lithuanian Rivers

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Aleksandras Stulginskis University, Lithuania
Turku University of Applied Science

Abstract

The aim of the research is to determine whether the geostatistical modeling is suitable to analyze the spatial dispersion of the selected hydrological characteristic as well as to find out the level of accuracy of predicting the values of unexplored Lithuanian rivers using this method. The research analyzed 55 rivers and used values of spring flood peak discharge 1% probability ($A_{1\%}$) collected in 74 water measurement stations (WMS) located on these rivers. The best results of interpolation of the spring flood peak discharge 1% probability were obtained using Gaussian variogram model and Ordinary Kriging method. With this method, values of the spring flood peak discharge 1% probability for the unexplored rivers can be predicted with an error of 11.5%. The analysis of modeled values of the spring flood peak discharge 1% probability revealed that the most significant errors (>48%) were obtained with seventeen basins and 11 of them have area of up to 200 km$^2$ (values were twice as high as the analyzed ones), the greatest errors were obtained with 17. Moreover, it was noticed that significant errors are obtained when basins with highly different areas occur next to each other in the data set. Grouping of the analyzed water measurement stations by basin area into three groups was not effective, because errors remained high (15%, 4%, 7%) and counters occurred in the spatial dispersion maps. Following the reduction of the geographic parameter values with the basin area of 200 km$^2$ and after the geostatistical analysis of these values, it can be argued that significant errors remained with basins that cover small area; therefore, it is necessary to perform a more detailed analysis of basins where greater errors of the hydrological characteristic have been obtained.

Keywords: Geostatistical modelling, Kriging method, spring flood peak discharge 1% probability

Introduction

When designing various water facilities, it is often necessary to carry out hydrologic calculations. One of the hydrological characteristics to be calculated is spring flood peak discharge. On the basis of studies of Russian scientists D. Sokolovsky, K. Voskresensky, A. Alekseev et al, normative documents for the calculation of peak discharge have been prepared in 1937 and remain valid to this day. Application of these methods to the Lithuanian rivers has been extensively examined by J. Macevičius (Macevičius, 1969); during the post-war years, with more hydrometric data available, peak discharge were studied by J. Žilevičius, J. Jablonskis, A. Žilénas, etc. When calculating the peak discharge using computational formulas, it is very important to determine their parameters as accurately as possible. To eliminate all the natural factors when calculating peak discharge, a parameter called spring flood peak discharge 1 % probability or the geographical parameter is used ($A_{1\%}$). For unexplored rivers (those that have not been subjects of hydrological observations), values of the geographical parameter are generally determined using the existing contour maps. It should be noted that most of them have been drawn manually relying on the expertise of the mapmaker. It is furthermore important to note that the data used when drawing a map may not always reflect the current situation.

Advances in computer technology opened up new capabilities in dealing with this issue. Such technologies include geographic information systems (GIS). These technologies enable the use of geostatistical analysis for the assessment of the spatial dispersion of hydrological characteristics and contour mapping.

Geostatistical analysis is well suited because the data points available are rarely well-located with respect to the points to be estimated, and the observed values are weighted to provide the best estimates. In addition to this procedure, the weights can be obtained by the methods of optimal interpolation or by simple Thiessen coefficients. Previously, Gottschalk. L. (1993a; 1993b) and Gottschalk. L. and Krasovskaiia (1998) suggested the potential use of kriging in network design. Kriging was originated by Matheron (1971) and first applied in mining (Delhomme, 1979); basic concepts are explained by Virdee and Kottekoda (1984) applied the technique to optimal well selection. Geostatistical interpolation are also of wide use for interpolation and integration of precipitation fields (Dingman et al, 1988; Barancourt et al, 1992, Arnell, 1995; Aragheinejad, Burn, 2005). There are also examples of the application of such methods to simplified assumptions for interpolation of runoff as a point process (Hisdal, Tveito, 1993; Sauquet et al., 2000).

The aim of the research is to determine whether the geostatistical modeling is suitable to analyze the spatial dispersion of the selected hydrological characteristic as well as to find out the level of accuracy of predicting the values of unexplored Lithuanian rivers using this method.

Object and Methods of the Reasearch

The research analyzed 55 rivers and used values of spring flood peak discharge 1% probability ($A_{1\%}$) collected in 74 water measurement stations (WMS) located on these rivers. The analysis employed values of the hydrological characteristic given in the book “Lietuvos upės. Hidrografija ir nuotėkis” (Lithuanian Rivers. Hydrography and Runoff) (Gailiušis et al., 2001).

The research employed ArcGIS program and the geostatistical analysis module of this program.

Moreover, the research used interpolation method called after the author D. G. Krige. The Kriging method is grounded on the following principle: variability of a phenomenon presented as z values is statistically homogeneous over the entire surface (Kumar, 2006; Jordan, 2003).
Kriging algorithms use a variety of mathematical functions for the modeling of spatial variability of \( z \) values between known points (Lebel, Bastin, 1985).

\[
Z(s) = \mu + \varepsilon(s),
\]

(1)

here: \( Z \) – value of the point, \( s \) – characteristic describing the location of the point, \( \mu \) – constant average value, \( \varepsilon \) – errors, depending on the position on the investigated surface.

Kriging interpolation is divided into ordinary, simple and universal. Simple Kriging is when interpolation is carried out on the basis of the mean of dispersion of values of points. This method provides the mean value of points surrounding the unknown point. Universal Kriging is different from the ordinary one in that here, the existing points used for interpolation regularly drift in a certain direction. The primary task of Ordinary Kriging is to present a semivariogram using the available data.

Kriging methods were assessed by calculating the statistical parameters: mean error (ME) – the closer to zero, the better, root mean square error (RMSE) – its value depends on the set of analyzed data, but the smaller the value, the closer modelled values to those analyzed are presented, average standard error (ASE) – has to be as close to the value of root mean square error as possible, if variability of analyzed values has been correctly assessed, mean standardized error (MSE) – should be close to zero, and root mean square standardized error (RMSSE) – should be as close to 1 as possible (Krivoruchko, Gribov, 2004; Knight et al. 2005).

The program provides these parameters by carrying out a cross-testing procedure, where each value is modeled and compared with the actual one. The obtained difference between the actual value and modeled value is used to determine previously specified statistical parameters (Cheng et al., 2007; Goovaerts, 2000).

### Research Results and Discussion

Values of spring flood peak discharge 1% probability in 74 investigated centroids ranged from 0.54 m³/s to 2.19 m³/s. Guntauninkų WMS on the Svyla River was distinguished by the lowest value in the target data queue, whereas the greatest value was characteristic of Ruzgių WMS on the Varduva river. The most often recurring values in the analyzed initial data set ranged from 1.22 m³/s to 1.39 m³/s (19 WMSs), other often recurring values ranged from 1.39 m³/s to 1.56 m³/s (10 WMSs) and 0.54 m³/s to 0.71 m³/s (8 WMSs). Mean of the analyzed A₁% values was 1.271 m³/s.

For the purposes of determining A₁% values in the unexplored rivers, one of geostatistical analysis methods, i.e. Kriging, was used. The initial data set was tested using all three Kriging methods. The first step in the analysis was to select the variogram model. After the calculation of half-variances, experimental variogram models were drawn up and theoretical Gaussian model was selected as the most appropriate one, inasmuch as the nugget for this model is very low (0.12) and almost equal to zero. This value is assigned to the measurement uncertainty, where the measurement of the same characteristic in the same location gives different results.

Another important step was to correctly select parameters of the method that influence the accuracy of modeled values. Then, the range size, number of adjacent points was determined; interpolation scheme presents the most accurate results of modeled values.

For the purposes of further geostatistical analysis, a range of 26.9 km was selected, because with this range, the best connection between modeled and analyzed values (0.64) was obtained; with reduced range the accuracy decreased, eg. with the range of 15 km, correlation coefficient decreased to 0.6. When assessing what number of points increases the accuracy of modeled values, sets of 3, 6, 9 and 12 adjacent points were tested. The best interpolation results (modeled values closest to the analyzed ones) were obtained with 6 adjacent points. For the purposes of modeling, circular search scheme for adjacent points divided into sections of 45° was chosen, because this scheme provided the best results, which are discussed in this article.

When performing cross-testing procedure according to the selected variogram model and the aforesaid parameters, modeled values are calculated and compared with analyzed values in that point. The statistical parameters given in Table 1 allow for comparing the reliability of prediction and error values.

<table>
<thead>
<tr>
<th>Kriging methods</th>
<th>Mean error, m³/s</th>
<th>Root mean square error, m³/s</th>
<th>Average standard error, m³/s</th>
<th>Mean standardized error, m³/s</th>
<th>Root mean square standardized errors, m³/s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ordinary</td>
<td>0.016</td>
<td>0.302</td>
<td>0.311</td>
<td>0.035</td>
<td>0.957</td>
</tr>
<tr>
<td>Simple</td>
<td>0.025</td>
<td>0.372</td>
<td>0.396</td>
<td>0.060</td>
<td>0.990</td>
</tr>
<tr>
<td>Universal</td>
<td>0.016</td>
<td>0.302</td>
<td>0.311</td>
<td>0.035</td>
<td>0.957</td>
</tr>
</tbody>
</table>

Modeled values obtained using Ordinary and Universal Kriging are identical, just like the key geostatistical parameters. In terms of root mean square standardized value 0.99 m³/s, Simple Kriging is best for generating A₁% values, because with this method the value is closest to 1. In terms of mean error, this value is 0.025 m³/s (with Simple Kriging) and is greater than that obtained using Ordinary or Universal Kriging, i.e. closer to zero (0.016 m³/s). When modeling the values using Ordinary Kriging, 77% of errors fall in the range of + 0.302 m³/s and -0.302 m³/s.

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The mean of values modeled by means of Ordinary Kriging is 1.287 m$^3$/s which is 1.24% higher than the mean of the analyzed values; the mean of values modeled by means of Simple Kriging is 1.295 m$^3$/s, i.e. 1.85% higher than the mean of analyzed values. Thus, Simple Kriging results in greater errors.

When comparing analyzed and modeled values obtained by means of Ordinary Kriging, the errors range from 0.001 m$^3$/s to 0.69 m$^3$/s; error of 5% was not exceeded only in 12 WMSs. In 11 WMSs, a limit of 10% was not exceeded. When assessing modeled values of the analyzed characteristic obtained by means of Simple Kriging, 11 WMSs stay within the allowed limit of 5%; errors do not exceed the limit of 10% in exactly the same number of WMSs. The analysis of modeled values shows that Ordinary Kriging provides values that are closer to the calculated ones (Fig. 1, a), correlation coefficient $R=0.64$; whereas with Simple Kriging $R=0.60$.

Ordinary Kriging method was used to develop a spatial dispersion map of the hydrological characteristic (Fig. 1, b). With the existing spatial dispersion map for the spring flood peak discharge 1% probability, it is possible to choose values of the analyzed characteristic of the unexplored rivers with 11.5% accuracy.

The largest errors were obtained in Guntauninkų WMS on the Svyla River: calculated value is 0.54 m$^3$/s, modeled values using ordinary and simple method respectively are 1.17 m$^3$/s and 1.26 m$^3$/s; Santaukų WMS on the Vilnia River: 0.62 m$^3$/s, modeled values – 1.17 m$^3$/s and 1.306 m$^3$/s; Talačkonių WMS on the Ištro River: analyzed value is 0.59 m$^3$/s, modeled values are 1.287 m$^3$/s and 1.242 m$^3$/s.

In summary, modeled values in all these 11 WMSs were twice as high as the analyzed ones. Review of the rivers revealed that they fall into different hydrological areas. 2 rivers in the Western Lithuania: Šustis-Jonaičiai, Aunuva-Aunuvenai; 4 rivers in the Central Lithuania: Štras-Talačkoniai, Nevėžis-Kerblonis, Pedamė-Antakalniai, Šešupė-Kalvarija; 5 rivers in the Southeast Lithuania: Svyla-Guntauninkai, Obeltis-Stakliskės, Vilnia-Santakai, Rudamina-Patotorys, Šventoji-Liukonys; therefore, it cannot be assumed that significant errors could be distributed in any one hydrological area.

As shown in Figure 1 b, a lot of counters around the centroids (so-called “bull’s eyes”) have been obtained. Inasmuch as counters or significant error areas are obtained, it can be stated that the density of water measurement stations is too low to reflect the geographical fluctuations of hydrological characteristics, or their arrangement is inappropriate.

The analysis moved on to verify the assumption that significant errors may have occurred due to the influence of basin sizes. When assessing the rivers in terms of basin area, the later ranges from 10.2 to 835 km$^2$, and the analysis of modeled values of the analyzed characteristic revealed that significant errors (>48%) were obtained in 17 basins and the area of 11 of these basins is up to 200 km$^2$; therefore, the highest errors in this case are obtained with small basins. Significant errors are moreover obtained where stations with different basin areas are located next to each other, eg. Svyla – Guntauninkų WMS, basin area 148 km$^2$ (0.54 m$^3$/s), Šventoji – Antalieptės WMS 565 km$^2$ (1.37 m$^3$/s) and Žeimenos – Pabradės WMS 2,580 km$^2$ (0.89 m$^3$/s). As we can see from the examples above, variation is observed not only with basin areas, but also with values of the spring flood peak discharge 1% probability. It is furthermore possible to assume that basins with different areas located next to each other may distort the accuracy of the modeled values.

To avoid significant error areas, it was decided to group basins covered by WMSs (centroids) according to areas and repeat the analysis of spatial dispersion of the analyzed characteristic. WMS (centroid) basins were grouped by their surface area into three groups: a) up to 200 km$^2$; b) from 201 km$^2$ to 1,000 km$^2$; c) larger than 1,001 km$^2$. The first group includes 21 river basins and the Pedame River basin with the smallest area (10.2 km$^2$), the second group includes 31 river basins and the third group consists of 22 river basins.

When analyzing the first group of basins, the analyzed values of the spring flood peak discharge 1% probability ranged from 0.54 m$^3$/s (Guntauninkų WMS - Svyla) to 2.17 m$^3$/s (Gudelių WMS – Rešketa). Comparing the modeled values before and after the grouping revealed that predicted values got closer to the measured ones after the grouping in 10 WMSs (48%). It was noticed that in WMSs with high $A_{1%}$ values (Rešketa - Gudelių and Babirungas – Užupių),
predicted values decreased after the grouping, i.e. the error increased and only in two WMSs (Paalsio on Alsa and Jackgalys on Juosta); predicted errors of the hydrological characteristic of the rivers do not exceed the limit of 5%. After basin grouping by areas and with Ordinary Kriging method, values in this group are modeled with an average error of 15%, which is a very large error, because it was 11.5% before the grouping. It was noticed that significant errors were obtained in the following stations: Šventoji-Večiai (data range 10 year), Babrungas-Užupiai (data range 15 year), Upita-Eidukiai (16 year) (analogue river Veiviržas-Mikužiai with basin area of 336 km²), Rudamina-Patotorys (9 year), i.e. those with a short range of analyzed data. Even though it cannot be asserted that the duration of observations has a close connection with the modeling results, but higher errors were obtained in stations with a shorter data range and interrupted series of observations (Rešketa-Gudeliai (40%) and Musė-Jauniūnai (36%), Vilnia-Santakai (22%)).

In individual cases, modeled values got closer to the calculated ones; however, the accuracy of modeled values did not increase sufficiently. Moreover, there was rather minor improvement of graphic image of spatial dispersion. This is clearly seen from the map obtained (Figure 2 a); counters still occur around the centroids. It can be argued that it is impossible to accurately assess spatial dispersion of the analyzed characteristic with a small amount of points at hand. As it was mentioned before, interpolation data set consists of data from only 21 basins, thus a lot of empty spaces are obtained where it is impossible to evaluate the reliability of the modeled values. As Figure 2 (a) shows, this group mainly includes stations located on Žemaičių Hill, whereas mid-Lithuanian area remains “empty”. During the interpolation, “empty” areas also occur in basins; therefore, it is difficult to compare the obtained results of geostatistical analysis with $A_{1\%}$ values calculated at WMSs. Thus, when performing geostatistical interpolation, it is very important to obtain the largest possible and the most accurate data set.

As expected, the analysis of $A_{1\%}$ spatial dispersion provided the best results when the second basin group was interpolated. When analyzing all analyzed values in this group and comparing them with the modeled ones, errors range from 0.02 m$^3$/s to 0.79 m$^3$/s, only in 7 WMSs errors do not exceed 5% limit; when comparing predicted values before and after the grouping, errors in 18 (58%) of WMSs decreased after the grouping. With Ordinary Kriging and after the grouping by basin areas, values in this group are predicted with a 4% error.

The final group where spatial dispersion of $A_{1\%}$ was analyzed includes river basins with area exceeding 1,000 km². When analyzing $A_{1\%}$ values calculated in this group, they range from 0.9 m$^3$/s (Pabradė-Žeimena) to 2.01 m$^3$/s (Jūra-Tauragė). The analysis of geostatistical parameters of the third basin group revealed that the value of root mean square standardized error (1.1 m$^3$/s) is higher than 1, which shows that the influence of the analyzed characteristic was overestimated. The analysis of the obtained spatial dispersion map (Figure 2 c) shows that there are still many counters around the analyzed points, because the number of the analyzed points (22) is too small to reflect the dispersion of the analyzed characteristic throughout the territory of Lithuania. Errors in this group range from 0.005 m$^3$/s to 0.60 m$^3$/s,
and the comparison of modeled values with predicted ones obtained before the grouping revealed that interpolation errors decreased in 12 WMSs (54%). Interpolation by means of Ordinary Kriging method allows for modeling $A_{1\%}$ values with an average error of 7%.

As the results of the analysis reveal, even though errors of the modeled characteristic decreased in the second and third group, the graphic image shows (Figure 2 a and c) that the number of analyzed points is too small to enable proper assessment of spatial dispersion of the analyzed characteristic throughout the territory of Lithuania.

As mentioned above, the worst results of spatial dispersion of the analyzed characteristic (with 15% error), where modeled values are compared with the analyzed ones, were obtained in the basin group with basin areas of up to 200 km$^2$. For the purposes of finding the most appropriate spatial analysis option, the analyzed characteristic was recalculated with the same basin area of 200 km$^2$, as recommended in the references (Macevičius, 1969). The characteristic was restested using the Ordinary Kriging method in order to determine the change in the accuracy and spatial dispersion of the modeled values.

With Ordinary Kriging, mean error was very low: 0.003 m$^3$/s, it has dropped by approximately 81% when compared with mean error obtained before recalculation of $A_{1\%}$ values; however, this does not confirm that the accuracy of modeling has improved. The reduction of analyzed values respectively resulted in reduced predicted values and errors. The comparison of modeled values with the analyzed ones revealed that the greatest differences were obtained in 8 WMSs. Modeled values in these stations were on average 0.24 m$^3$/s higher than the analyzed ones. The most significant mismatches between the analyzed and modeled values were obtained with small river basins, where basin area ranges from 10.2 to 219 km$^2$; here, significant differences between the analyzed and modeled values were obtained before the recalculation as well. This may be due to errors in the initial data, i.e. analyzed characteristics.

Comparison of newly developed spatial dispersion map of $A_{1\%}$ characteristic (Figure 2 d) with that obtained before the recalculation (Figure 1 b) reveals that the recalculation has lead to fewer counters and the greatest values remain mainly in Žemaičių Hill and the upper reaches of the Nevėžis River (as in the previous map).

When comparing modeled values with the analyzed ones, the average connection was $R=0.62$, before the recalculation it was $R=0.64$, thus after the recalculation of $A_{1\%}$ values, the accuracy of modeled values has not improved. In the given case, modeled values can be predicted with an error of approximately 14%, which is 2.5% higher than that obtained before the recalculation.

Conclusions

The best results of interpolation of the spring flood peak discharge 1% probability were obtained using Gaussian variogram model and Ordinary Kriging method. With this method, values of the spring flood peak discharge 1% probability for the unexplored rivers can be predicted with an error of 11.5%.

The analysis of modeled values of the spring flood peak discharge 1% probability revealed that the most significant errors were obtained with eleven rivers (values were twice as high as the analyzed ones). All of the aforesaid rivers are located in different hydrological areas; therefore, it cannot be assumed that significant errors could be distributed in any one hydrological area. Moreover, it cannot be explicitly argued that the duration of observations has a close connection with the modeling results. However, greater errors were obtained in stations with a shorter and interrupted range of observations.

The analysis of spatial dispersion of the geographical parameter by means of Ordinary Kriging method showed that the greatest errors (>48%) were obtained with 17 basins and 11 of them have area of up to 200 km$^2$. Moreover, it was noticed that significant errors are obtained when basins with highly different areas occur next to each other in the data set.

Grouping of the analyzed water measurement stations by basin area into three groups was not effective, because errors remained high (15%, 4%, 7%) and counters occurred in the spatial dispersion maps, inasmuch as the number of water measurement stations is too low to enable the assessment of dispersion of the interpolated characteristic throughout the territory of Lithuania. It can be assumed that proper assessment of spatial dispersion of hydrological characteristics is only possible with a sufficient amount of points.

Following the reduction of the geographic parameter values with the basin area of 200 km$^2$ and after the geostatistical analysis of these values, it can be argued that significant errors remained with basins that cover small area; therefore, it is necessary to perform a more detailed analysis of basins where greater errors of the hydrological characteristic have been obtained.

References


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Identification and Analysis of Forest Disturbances and Fragmentation in Giurgeu Mountains, Romania, Using Landsat Data

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Abstract

The environment is subject to continuous changes caused by natural or anthropogenic factors that have important consequences. The main aim of this study is to identify and analyse forest disturbances and fragmentation caused by uncontrolled timber harvesting and illegal logging. The analyses were carried out on a series of Landsat Thematic Mapper (TM) and Landsat Enhanced Thematic Mapper Plus (ETM+) temporal images aquired in 1987, 1993, 2002 and 2009. The images were processed using the Tasseled Cap (TC) transformation as the basis for calculating the disturbance index (DI). The applied method was that of image disturbance index difference, and the resulting thresholds were used in the end to obtain disturbances maps including three classes: fragmented, nonforest and forest. Starting from these maps ten metrics related to area, edge, shape, and core area were analysed for each class and each period. The results indicate that in the period 1987-2009 a strong forest fragmentation took place as a result of uncontrolled timber harvesting and of illegal logging which eventually led to the loss of the specific forest environment, of connectivity, of the habitat of different species and to surface erosion.

Key words: disturbance index, forest fragmentation, core area, shape metrics

Introduction

Global environmental changes are the result of the anthropogenic impact on land cover and land use. One of these changes is represented by the massive logging of the last decades which affected the climate and the biodiversity. The logging is generally present in countries where the strive for profit is not counterbalanced by adequate legislation. Such actions lead to landscape fragmentation and, consequently, to forest fragmentation causing the disappearance of the environment and of the connectivity specific to these ecosystems.

Natural disturbances cause different changes to the forest landscape than the anthropogenic disturbances such as timber harvesting. Thus, natural disturbances result in patches with less edge effect between them as compared to timber harvesting (Tinker et al., 1998). Clear cutting practices, as opposed to landscape patterns created by natural disturbances, lead to small surface patches, small perimeter patches, more edge habitat, larger distances between patches and less interior habitat (Hudak et al., 2007). Timber harvesting fragments the landscape through a distinct series of structural changes including the decrease of forest patch core area and mean patch size and the increase of patch density and edge density (Tinker et al., 1998). Also, timber harvesting tends to eliminate a larger volume of biomass as compared to natural disturbances (Tinker et al., 1998). Disturbances such as gypsy moth defoliation and logging lead to the reduction of soil nutrients (Goodale and Aber, 2001) and to canopy cover (Bormann and Likens, 1979).

Lately, the Landsat data have been used more and more successfully to map disturbances at the landscape scale (Kennedy et al., 2007; Cohen et al., 2010). Particularly, the disturbance index (Healey et al., 2005) was employed successfully in mapping disturbances in a variety of forest types (Eshleman et al., 2009; DeRose et al., 2011).

This article presents the results deriving from certain landscape metrics using a multitemporal series of Landsat TM images aquired from an area affected by loggings in Giurgeului Mountains, Romania. The specific objectives of this research are: (1) to identify disturbances caused by uncontrolled timber harvesting and illegal loggings; (2) to analyse the forest fragmentation resulting from these actions.

Materials and methods

Study area. The studied area is located in the southern part of Giurgeu Mountains in Harghita county, Romania, between 46°42'07"-46°54'28" north latitude and 25°15'21"-25°24'11" east longitude (Fig. 1). The studied area covers 25921 ha and includes forests, pastures, hayfields, agricultural land, built-in areas, roads and water bodies. The altitude ranges from 740 meters to 820 meters. The forests are made up mostly of spruce (Picea abies) but also of small percentages of fir (Abies alba) and beech (Fagus sylvatica).

Materials. The study used four frames clipped from Landsat satellite images belonging to path 183, row 28. They are part of a temporal series of Landsat images aquired on the 14.09.1987 (TM), 14.09.1993 (TM), 10.05.2002 (ETM+) and 24.07.2009 (TM). The images were downloaded from the Internet (http://glovis.usgs.gov). In processing them, we used only the multispectral bands whose spatial resolution is of 30 meters.
Figure 1. Studied area and the surfaces of classes for the three periods

Image preprocessing. The Landsat images were georeferenced in the Universal Transverse Mercator (UTM) system, zone 35 N, datum WGS 84, using 16 well distributed ground control points and the nearest neighbour resampling method. The root mean square error (RMSE) was of 0.25 pixels (7.5 m) for each image. The images obtained were radiometrically calibrated for conversion from digital number (DN) to satellite radiance unit (L) after which, in order to obtain the values of the reflectance at the top of the atmosphere (TOA), the radiance values were converted using the equation provided by Chander et al. 2009. By applying these corrections we have eliminated the effect caused by the zenith solar angle which differs according to the different time and acquisition date. TOA reflectance also allows the correction of the varying distance Earth-Sun on the different acquisition dates. For image correction we used the Dark Object Subtraction (DOS) model (Chavez 1996) considered the best in eliminating the atmospheric effect from the change detection applications (Song et al., 2001).

Image classification. Before calculating the DI a mask was used for the 1987 image to cover the nonforest surfaces and it was applied for each image when setting the DI. The accuracy assessment of this mask was 93.45% and was obtained by verification the reference data (stand maps, cadastral maps and photograms). The Tasseled Cap transformation was calculated for each image using the coefficients from the Idrisi programme, thus reducing the six Landsat TM bands to brightness, greenness and wetness. The three TC bands obtained were normalised by subtracting the average from the value of each pixel and then dividing by the standard deviation. After it was normalised, the DI was calculated by deducting from the brightness the value obtained by adding the greenness and wetness (Healey et al., 2005).

Healey et al. (2005) suggest that large positive DI values indicate a disturbed area, with little vegetation, while a large negative DI value indicates surfaces with increasing vegetation, whereas values close to zero represent no change surfaces. The DI values were calculated for each image considering that they reflect the situation for the period under investigation. Then, the DI values were subtracted from the previous image obtaining images of the differences for the periods 1987-1993, 1993-2002, 2002-2009 and 1987-2009 (Fig. 2). These were reclassified taking into consideration 1-2 standard deviations from the average, given that the extreme values have changed in terms of loss or occurrence of forest vegetation. Establishing the thresholds was based on the existing data, on the statistical data and on field trips for 2009. Each image obtained was filtered using a median 3x3 filter to eliminate the isolated pixels.

Forest fragmentation. It represents the process through which a landscape matrix is progressively divided in smaller and isolated patches, mainly as a result of forest harvesting and illegal loggings. The metrics were computed at the class level, with the following classes: fragmented, forest, and nonforest. The fragmented class includes the surfaces affected by uncontrolled forest harvesting and illegal loggings, obtained as a result of calculating the DI and obtaining the differences for each period. In order to avoid surfaces smaller than 900 m², as mentioned before, the images were filtered. The edge width for core metric calculations was 60 m. The metrics selected for analysis are presented in table 1.

Results and discussion

The studied metrics were selected so that they characterize the structure of the landscape at the moments in question and be representative. Patch area and variability metrics help achieve a general characterisation of the landscape structure. The sizes, edge volume and shapes of patches express the interaction among the distinct types of patch and, consequently, the flow of species within the landscape (Laurance and Bierregaard, 1997; Batistella et al., 2003). Other metrics like edge, shape, core area are important in applications concerning the study of edge effects and interior habitat (Batistella et al., 2003).
Table 1. Metrics used to assess landscape structure

<table>
<thead>
<tr>
<th>Index type</th>
<th>Abbr.</th>
<th>Units/value range</th>
<th>Hierarchical level</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area metrics</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of Patches</td>
<td>NP</td>
<td>(number)/0 &lt; to ∞</td>
<td>Class, Landscape</td>
<td>McGarrigal and Marks (1995)</td>
</tr>
<tr>
<td>Mean Patch Area</td>
<td>MPA</td>
<td>(ha)/0 &lt; to ∞</td>
<td>Class, Landscape</td>
<td>McGarrigal and Marks (1995)</td>
</tr>
<tr>
<td>Patch Area Standard Deviation</td>
<td>PASD</td>
<td>(ha)/0 &lt; to ∞</td>
<td>Class, Landscape</td>
<td>McGarrigal and Marks (1995)</td>
</tr>
<tr>
<td>Edge metrics</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Edge Density</td>
<td>ED</td>
<td>(m/ha)/0 &lt; to ∞</td>
<td>Class, Landscape</td>
<td>McGarrigal and Marks (1995)</td>
</tr>
<tr>
<td>Shape metrics</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean Shape Index</td>
<td>MSI</td>
<td>(none)/1 ≤ to ∞</td>
<td>Class, Landscape</td>
<td>McGarrigal and Marks (1995),</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>after Patton (1975)</td>
</tr>
<tr>
<td>Area Weighted Mean Shape Index</td>
<td>AWMSI</td>
<td>(none)/1 ≤ to ∞</td>
<td>Class, Landscape</td>
<td>McGarrigal and Marks (1995),</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>after Patton (1975)</td>
</tr>
<tr>
<td>Mean Fractal Dimension Index</td>
<td>MFDI</td>
<td>(none)/1 ≤ to 2</td>
<td>Class, Landscape</td>
<td>Burrough (1986)</td>
</tr>
<tr>
<td>Core area metrics</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Core Area</td>
<td>TCA</td>
<td>(ha)/0 &lt; to ∞</td>
<td>Class, Landscape</td>
<td>McGarrigal and Marks (1995)</td>
</tr>
<tr>
<td>Mean Disjunct Core Area</td>
<td>MDCA</td>
<td>(ha)/0 &lt; to ∞</td>
<td>Class, Landscape</td>
<td>McGarrigal and Marks (1995)</td>
</tr>
<tr>
<td>Mean Core Area Index</td>
<td>MCAl</td>
<td>(%)/0 to 100</td>
<td>Class, Landscape</td>
<td>McGarrigal and Marks (1995)</td>
</tr>
</tbody>
</table>

Number of patches (NP) is a simple measure of the extent of subdivision or fragmentation of the patch type and was calculated for each period. The highest NP value of fragmented class, of 731 (2.82 patches/100 ha), was recorded in the period 1987-1993, afterwards it dropped to 295 (1.14 patches/100 ha) in the period 2002-2009 (Fig. 3a). This shows that the period 1987-1993 marks the beginning of harvesting. In fact, the year 1987 was considered a reference one, however, according to the statistics, harvesting started after 1989. They affected the edge of forest covered mountains and affected especially small and isolated forests. By contrast, NP of forest class rose from 163 (0.63 patches/100 ha) in 1987-1993 to 327 (1.26 patches/100 ha) in 2002-2009 (Fig. 3a). The number of forest patches doubled, which can be explained by the surfaces affected by loggings. Thus, uncontrolled timber harvesting and illegal loggings resulted in the fragmentation of forests and of bare areas, without vegetation. As the harvesting progressed, the fragmented patches increased leading to a NP decrease and the increase of mean patch area. Consequently, forest patches increased in number and density while the mean patch area decreased. NP of nonforest class remained approximately constant, with slight fluctuations, which would explain the fact that bare surfaces, without vegetation, were created inside forests.

Mean Patch Area (MPA) represents an important indicator to evaluate the landscape transformation and fragmentation because the total amount of energy and nutrients in a patch is proportional to its surface (Forman and Godron, 1986). MPA of fragmented class in 1987-1993 was of 2.50 ha after which, in 1993-2003, it rose to 4.93 ha, and in 2003-2009 slightly fell to 4.91 ha (Fig. 3b). MPA of forest class in the period 1987-2009 was reduced to half, while for the nonforest class it remained, with small variations, the same (Fig. 3b). The period 1987-1993 was characterized by a small value of the MPA of fragmented class given the large number of patches (Fig. 3a). In the periods 1993-2002 and 2002-2009, MPA of fragmented class doubled while the MPA for forest class was reduced to half. When forest harvesting progressed, the forest patches were divided in smaller ones leading to a rise in NP as well as in the MPA of fragmented class.
Figure 3. Metrics used in the analysis

Patch Area Standard Deviation (PASD) is the dispersion metrics which follows the trend observed for MPA. PASD of fragmented class increased five times during the period 1993-2002, as compared to 1987-1993, then, in the period 2002-2009 it remained approximately the same (Fig. 3c). The ascending trend was also followed by the PASD of nonforest class, but the growth was of around 20% for the entire period. PASD of forest class decreased for the entire period by around 34%. Thus, the highest variability in patch area was recorded for the fragmented class which increased over time, indicating that these surfaces grew larger and of different sizes as a result of uncontrolled timber harvesting and illegal loggings. The other two classes show no high variability, the decrease of PASD of forest class over time showing that towards the end of the period MPA decreased.

Edge Density (ED) is a metric which provides information about the lengths of the edge per hectare. ED of fragmented class displayed the highest values in the periods 1993-2002 and 1987-1993 and fell to 42% in the period 2002-2009 (Fig. 3d). In the period 1993-2002 ED of fragmented class represented around 94% of ED of forest class, while in the period 1987-1993, 80% of ED of forest class. The decrease in ED shows that the surfaces with fragmented patch decreased as their surface increased. ED of nonforest class showed no high amplitude from one period to the other.

Mean Shape Index (MSI) measures the complexity of the average patch shape in the landscape as compared to a standard shape and is based on the relationships perimeter-area. For the studied area, all the classes present values higher than 1 which means that the higher the values the more irregular the shapes of patches, further away from the
circular shape. In the period 1987-1993 MSI showed the highest values (Fig. 3e) for all the classes, which explains the more elongated shape of patches (Fig. 2). In the period 2002-2009 MSI fell, the shape of patches being no longer so elongated because of the timber harvesting which was concentrated in the same areas where it had started the previous years. Thus, the fragmented areas extended in all directions leading to larger and rounder patches.

Area Weighted Mean Shape Index (AWMSI) measures the edge quantity in a reported class to the one recorded in a class of the same size but which has a circular shape. In calculating the average shape of patches, AWMSI weights larger patches more heavily than the smaller ones. Shape and size of patches dictate the extension of the perimeter and edge as compared to the other neighbouring patches. These perimeter-area relationships quantified by one metric are complicated and, often, difficult enough to interpret (Frohn, 1998; Batistella et al., 2003). AWMSI of fragmented class increased during the analysed period, a significant increase occurring from the period 1987-1993 to 1993-2002 (Fig. 3f). The increase is due to the fact that the fragmented patches increased considerably during the last two periods (Fig. 3b). AWMSI of the forest class was reduced considerably because of forest fragmentation, MPA of forest class decreasing to half for the entire period.

Mean Fractal Dimension Index (MFDI) is another basic type of shape index which characterizes the shape of patches on the basis of the perimeter-area relationships. A value close to 1 indicates a shape with a simple perimeter such as circle or square, whereas a value close to 2 indicates a much more complicated shape. For all the classes, the values MFDI are close to 1 which shows, just like MSI, that the shape of patches is closer to the circular one (Fig. 3g). Although the values are very close for the three periods, the values displayed for the period 1987-1993 were slightly higher followed, in descending order, by the periods 1993-2002 and 2002-2003. Taking into consideration the MEDI values for the studied area and the classes considered, in time the shape of the patches tends towards the circular one.

Total Core Area (TCA) represents the sum of the area in the patch greater than the specified depth-of-edge distance from the perimeter, in this case 60 m. The smallest TCA of fragmented class was recorded in the period 1987-1993, increasing considerably in 1993-2002 after which it fell again in the period 2002-2009 (Fig. 3h). According to this metrics, in the period 1993-2002 fragmented patches presented the largest areas, as also shown by the MPA, which led to the accumulation of core area. This phenomenon can be observed in figure 2, the most affected area being the central south one, which is also the area contributing the most to the TCA of fragmented class. TCA of forest class was smaller during the period 1993-2002 given the rise of TCA of fragmented class. In this period, uncontrolled timber harvesting and illegal loggings were concentrated more in certain areas, harvesting surfaces of hundreds of hectares. During the period 2002-2009 the loggings on large surfaces were concentrated, mainly, in 3-4 areas (Fig. 2), without exceeding those recorded in the period 1993-2002, this is the reason why the TCA value of forest class is smaller than the one recorded in 1987-1993. TCA of nonforest class increased in the period 2002-2009 because of massive uncontrolled timber harvesting in several areas which led to the extension of the nonforest areas. According to statistical data, in the last 18 years, a large surface was systematically cut down. Massive loggings began in 1995 on the western side of the studied area then progressed towards the central south one until the forest disappeared completely on certain surfaces, between 2003 and 2006. In the studied period, over 1000 ha of spruce forest and 650 ha were harvested only between 2003 and 2006.

Mean Disjunct Core Area (MDCA) is a measure of the size of the individual core areas and is important in determining the functional size of the habitat patches for edge sensitive species. MDCA or interior patch areas results after specifying an “edge effect” buffer area. One of the main effects of forest fragmentation is the conversion of interior habitat to edge habitat (Tinker et al., 1998). MDCA of fragmented class recorded the lowest value in the period 1987-1993 (Fig. 3i) given the fragmentation method into larger and smaller patches. This metrics increased then in the two periods considering that the forest interventions were aimed at extending the surfaces. The increase of MDCA of fragmented class led to the decrease of MDCA of forest class for the entire studied period (Fig. 3i).

Mean Core Area Index (MCAI) is a relative index which measures the core area as a percentage of the total area. It is based on selecting an edge width that can be associated with the phenomenon under investigation. As these studies relate to the process of uncontrolled timber harvesting and illegal loggings, choosing an edge width of 60 m was based on the potential reactions of forests to such actions. MCAI relates to the concept of “interior habitat” which is very relevant for a certain number of species (Batistella et al., 2003). MCAI of fragmented class has always had a lower value for the period 1987-1993 and for most of the period 1993-2002 (Fig. 3j). MCAI of forest class decreased for the period 2002-2009. Thus, the increase of MCAI of fragmented class shows that during the studied period there was an increase of core areas as a result of timber harvesting which derived from expanding the surfaces where the harvesting initially began. It is clear that a higher value of the MCAI of the fragmented class means large surfaces affected by loggings. A decrease of MCAI of forest class shows forest fragmentation with reduced core areas.

Conclusions

The results obtained after analysing the Landsat TM and ETM+ satellite images show that, during the period 1987-2009, the studied area was affected by a strong process of forest fragmentation because of uncontrolled timber harvesting and illegal loggings. This is a widely spread phenomenon in the Romanian forests after 1989 when a part of the forests were given back to their former owners who harvested them, most of the time, without complying with forest laws. In the studied area, uncontrolled timber harvesting and illegal loggings began sporadically, along the edges of the mountains or in isolated areas, then it expanded to larger surfaces. The fragmentation of the forest led to the loss of its...
specific environment, to the modification of the local ecosystems, to the reduction of the biodiversity, of the connectivity, to the loss of the habitat of certain species and to the emergence of the surface erosion phenomenon.

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Ni$^{2+}$ Ion Removal from Contaminated Solutions Using Synthetic Zeolites

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Abstract

The adsorption of Ni$^{2+}$ ions from aqueous solutions onto two types of zeolites CaA and NaA has been investigated under batch mode. The influence of major parameters governing the efficiency of the process such as, adsorbent dose, initial concentration, solution pH, and contact time on the removal process was investigated. Nickel removal was studied using the working solutions with different Ni$^{2+}$ ion concentrations: 10, 25, 50 and 100 mg/L. Maximum adsorption duration – 120 minutes.

Time-dependent experimental study showed that nickel removal efficiency using zeolites CaA and NaA decreased with increasing of Ni$^{2+}$ ion initial concentration in the working solutions. Zeolite NaA showed better Ni$^{2+}$ ion removal efficiency than zeolite CaA. Already after 15 minutes of treatment with 1.0 g/50 mL of zeolite NaA at 10 mg/L of initial Ni$^{2+}$ concentration, metal removal percentage reached 97.6 %, while with zeolite CaA removal efficiency was almost twice as lower – 48.5 %. With increase of adsorbent dosage from 1.0 g/50 mL up to 2.5 g/50 mL, nickel ion removal efficiency from all the investigated solutions also increased. Removal percentage with 2.5 g/50 mL of zeolite NaA already after 30 minutes of exposure reached more than 95 %. With increase of adsorption duration and decrease of concentration of initial working solutions, pH under different adsorption conditions in most cases increased slightly, but variations were mainly insignificant.

Key words: heavy metals, nickel, adsorption, synthetic zeolite, removal efficiency

Introduction

Heavy metals such as cadmium, chromium, cobalt, copper, zinc, nickel and mercury are common water pollutants. These metals are found in aqueous wastes from industries, such as mining operations, metal plating, electronics, landfilling, etc. [Ji et al, 2012; Salomons at al., 1995; Mohan et al., 2007]. Among them, nickel is a toxic heavy metal found in the environment naturally, also in elevated concentrations as a consequence of industrial activities [Krishna et al, 2011]. Almost all heavy metals are dangerous substances that tend to accumulate in the environment and have long-term effects on ecosystems [Paliulis, 2006]. Contaminated soil can act as a sink – under certain circumstances heavy metals in the soil can migrate into groundwater, also reach surface water bodies [Anisimova et al, 2004]. An important source of heavy metals in the environment is effluents of industrial wastewater. Therefore, research in the field of removal of heavy metal ions from aqueous solutions is relevant seeking for cleaner environment [Ji et al, 2012].

Traditional methods of removing heavy metals from aqueous solutions include: chemical precipitation, oxidation/reduction processes, electrochemical treatment, filtration, ion exchange and membrane technologies. However, these processes may be ineffective or economically non-feasible, especially when concentration of metal ions in the solution ranges from 1-100 mg/L. In recent years, adsorption based processes have been widely studied as an alternative method for the removal of heavy metals from wastewater [Liang et al, 2009].

Among the various water treatment and recycling technologies, adsorption is a fast, inexpensive and versatile method to remove metals [Krishna et al, 2011]. Basically adsorption is the mass transfer process in which the material from the liquid phase is transferred onto a solid surface and is bound by physical and/or chemical interaction [Kurniawan et al, 2006]. Natural and synthetic zeolites can be used for the removal of heavy metals from aqueous solutions. This is a relatively cheap and effective technology for clean-up of contaminated waters [Anisimova et al, 2004]. Mosti et al. (2009) metal adsorption studies using natural zeolite-clinoptilolite exhibited a rapid response within the first 40 minutes, which corresponds to 80% of the total adsorbed amount. After this initial period of rapid metal removal is over, rate of adsorption process decreases. Specific field of zeolite application depends upon its structure-defined properties.

The aim of this work was to study the adsorption efficiency of 2 different types of synthetic zeolite on the removal of Ni$^{2+}$ ions from aqueous solutions.

Materials and Methods

Ni (II) stock solution of 1 g/L was prepared by dissolving the accurately weighed required amount of nickel salt (NiSO$_4$·6H$_2$O) in the bi-distilled water. Aqueous working solutions of different concentrations used in metal adsorption experiment were prepared by diluting the stock solution. Nickel ion concentration in the working solutions was as follows: 10 mg/L, 25 mg/L, 50 mg/L and 100 mg/L. The weight of adsorbents used in this study – synthetic granular zeolite NaA and zeolite CaA, was 1.00 g and 2.50 g respectively for different adsorption experiments. After weighing the adsorbent, it was poured into 50 mL of the working solution of the appropriate Ni$^{2+}$ concentration and mixed at 160 revolutions per minute during the whole experiment. Solution pH was measured and 1 mL of the sample was taken every 5, 15, 30, 60 and 120 minutes. After sampling, 1 mL of the working solution was diluted up to 50 mL with bi-distilled water, and concentration of heavy metals in the samples was determined by inductively coupled plasma optical emission spectroscopy (ICP-OES). All adsorption experiments were carried out at a temperature of +19.1°C.

Adsorption efficiency was evaluated by changing parameters affecting the adsorption process: nickel concentration of the working solution, zeolite amount used for adsorption as well as process duration. Changes in pH were also observed during the adsorption experiment.
After determination of heavy metal concentration (mg/L) in the working solutions, adsorbent (zeolite) ability to remove heavy metals from the aqueous solution was calculated as quantity of metal ions adsorbed by a unit mass of an adsorbent at equilibrium using the following equation:

\[ Q_e = \frac{V (C_0 - C_t)}{M} \]  

where:
- \( Q_e \) – amount of metal ions adsorbed on zeolite from the aqueous solution at equilibrium (mg/kg),
- \( C_0 \) – initial metal ion concentration in the solution (mg/L),
- \( C_t \) – metal ion concentration in the solution after adsorption at time \( t \) (mg/L),
- \( M \) – mass of the adsorbent (kg),
- \( V \) – amount (volume) of the aqueous solution used for the adsorption study (mL).

Metal adsorption efficiency was also calculated in percentage of the removed metal ions from the aqueous solution and expressed as removal percentage:

\[ R_\% = \left( \frac{(C_0 - C_t)}{C_0} \right) \times 100 \% \]  

Results and Discussion

The influence of major parameters governing the efficiency of metal adsorption process such as, sorbent dose, initial Ni\(^{2+}\) ion concentration as well as contact time on the removal process was investigated. Changes in the solution pH have also been observed during the adsorption, under different conditions.

Data of heavy metal removal efficiency from the solutions with different NiSO\(_4\).6H\(_2\)O concentration shows the differences of zeolite structure and amount defined adsorption process (Fig. 1-4).

Results prove that adsorption proceeds actively from the first minutes of zeolite addition. During the first 5 minutes 1.0 g/50 mL of synthetic zeolite CaA removed nearly 50 % of nickel ions in the case when initial concentration of metal ions was 25 mg/L, and the lowest efficiency after 5 minutes was in the case of 50 mg/L of initial concentration – 24.61 % (Fig. 1). Finally, after 120 minutes of treatment the major part of the Ni\(^{2+}\) ions (93.9 %) has been removed by zeolite CaA when initial metal ion concentration was 10 mg/L, whereas removal percentage reached more than 80 %, in the case of 25 mg/L initial Ni\(^{2+}\) solution. Final removal efficiency (after 120 min) from 100 mg/L and 50 mg/L Ni\(^{2+}\) working solutions was lower than that from less concentrated solutions, and reached 50 % and 60 % accordingly. Time-dependent experimental study showed that nickel removal percentage decreases with increasing of its initial concentration in the working solution.
Nickel removal rate using 1.0 g/50 mL of synthetic zeolite NaA as adsorbent was even higher than in the case of zeolite CaA (Fig. 2). Ni$^{2+}$ removal percentage reached 97.62 % after 15 minutes of exposure in the case of 10 mg/L of initial Ni$^{2+}$ concentration. This zeolite also appeared to be more efficient after 120 minutes of exposure. All removals were above 95 %, and the best adsorption result (99.8 %) was achieved from 50 mg/L of the initial working solution.

When adsorbent dosage was increased up to 2.5 g/50 mL, nickel removal efficiency from aqueous solutions also increased (Fig. 3-4). After 2 hours of treatment with zeolite CaA the lowest metal adsorption efficiency was in the case of 100 mg/L initial Ni$^{2+}$ solution (Fig. 3). Removal percentage from the three other working solutions was above 90 %. And again, experimental study showed that nickel removal percentage decreases with increasing of its initial concentration in the working solution.
Adsorption results with 2.5 g/50 mL adsorbent zeolite NaA again proved it being more efficient in the removal of Ni$^{2+}$ ions to compare with zeolite CaA (Fig. 4). After 5-minute interaction with zeolite NaA, it adsorbed 80.5 % of Ni$^{2+}$ ions, whereas zeolite CaA – 50.4 %; the highest metal adsorption efficiency being in the case of 25 mg/L initial Ni$^{2+}$ solution. After 2 hours treatment with zeolite NaA the best metal adsorption efficiency was in the case of 50 mg/L initial Ni$^{2+}$ solution – removal percentage was as high as 99.97 %. It should be noted that removal efficiency of zeolite NaA was better in all cases – when adsorbent dosage was 1.0 g/50 mL equilibrium was reached after 1 hour of interaction, and when adsorbent dosage was increased up to 2.5 g/50 mL equilibrium was reached already after 30 minutes of interaction in all the working solutions. Kocaoba et al. (2007) using clinoptilolite for heavy metal removal studies found out that the adsorption process was very fast and the maximum adsorption efficiency was achieved already during the first hour of exposure – after 60 minutes with all concentrations tested equilibrium was reached. Results of this study showed that equilibrium using zeolite NaA can also be reached in one hour after the start of the reaction, however, adsorption process with zeolite CaA is slower and equilibrium was reached only after 2 hours of interaction, and only in the case of lower initial concentration of Ni$^{2+}$ ions.

During all the adsorption experiment changes of pH values in the aqueous working solutions were monitored. The results showed that in all cases solution pH was slightly alkaline.

During the adsorption with zeolite NaA, pH value of the solution when Ni$^{2+}$ concentration is 10 mg/L after 5 min of treatment was 8.5, and after 120 minutes – 8.6. For the solution of 100 mg/L, these pH values were 7.9 and 8.8, respectively (Fig. 5). The results of this experiment showed that with time the solution pH using zeolite NaA changed from neutral to slightly alkaline in the case of higher nickel concentration in the solution. No significant change of pH was observed within the different Ni$^{2+}$ concentration range.
During the adsorption with zeolite CaA, pH value of the solution when Ni\(^{2+}\) concentration is 25 mg/L after 5 min of treatment was 7.5, and after 120 minutes – 8.2 (Fig. 6). For the solution of 100 mg/L, the pH value remained constant. The results of this experiment showed that with time the solution pH variation using zeolite CaA was insignificant. When Ni\(^{2+}\) concentration in the working solutions decreased, the pH value increased slightly: from 7.5 up to 8.8 after 120 minutes of treatment.

**Conclusions**

Time-dependent experimental study showed that nickel removal efficiency using zeolites CaA and NaA decreased with increasing of Ni\(^{2+}\) ion initial concentration in the working solutions.

Zeolite NaA showed better Ni\(^{2+}\) ion removal efficiency than zeolite CaA. Already after 15 minutes of treatment with 1.0 g/50 mL of zeolite NaA at 10 mg/L of initial Ni\(^{2+}\) concentration, metal removal percentage reached 97.6 %, while with zeolite CaA removal efficiency was almost twice as lower – 48.5 %.

With the increase of adsorbent dosage from 1.0 g/50 mL up to 2.5 g/50 mL, nickel ion removal efficiency from all the investigated solutions also increased. Removal percentage with 2.5 g/50 mL of zeolite NaA already after 30 minutes of exposure reached more than 95 %.

With the increase of exposure duration and decrease of the concentration of initial working solutions, pH under different adsorption conditions in most cases increased slightly, but variations mainly were insignificant.

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Capability Assessment of Application of Software MIKE URBAN for Rural Water Distribution System Operation Optimization

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Abstract

Balancing all elements, operating in water supply systems, provides a cost effective, reliable and high quality water supply to consumers. The capability of operation of water distribution systems using software package MIKE URBAN were analysed in this article. As case study water distributions system of residential area in Radikiai settlement, Kaunas district municipality was selected. An operation of this newly designed system was analysed using modern specialized software. Results show that the designer using this program can properly assess the correct pressure in networks in water supply for daily consumption and in cases of fire and to assess the water age in pipes because of diameter of pipes being too large. The water age study showed that the maximum water continuance in network is over 4 hours.

Key words: water supply, software Mike Urban

Introduction

Every user hopes for good quality water for the lowest available price. Most water supply systems in towns and settlements in Lithuania were designed and constructed in Soviet time. Nowadays, due to reduction in water use, exploitation of existing water distribution networks (especially in small settlements) became uneconomic. Water users in small settlements are faced with a number of problems concerning water supply – the water supply is of a too low pressure, the lack of pressure in case of fire, deterioration of quality of the water supply and so on.

Gunhui Chung et al (2008) states, that the small water supply systems (in settlements) can be more cost-effective than in town. In this case, the price mainly depends on the water source.

The optimal scheduling of pumps is measured as to minimize cost and improve operational conditions (Ormsbee L. et al, 2009). In most countries around the world much attention is paid to research the congruence of water consumption and water supply schedules, i.e. trying to find a solution that best fits the needs of water supply users. Some successful applications have been carried out in the United States in the city of Pittsburgh. The simulation results showed that setting up optimal daily pump schedules for the water supply can reduce the price up to 20 percent (Nitivattananon V. et al, 1996).

Despite the rapid development of modelling methods in the water industry, some problems of water distribution network modelling are still unresolved, such as how to adequately represent real demand and losses. Both are dependent upon service pressure. Dušan Obradovič argues that this problem is given too little attention (Obradovič D., 2000). By this author 'obviously much, much more data are needed from the field and of the better quality'. Apart from using the usual sources of information (telemetry, water bills, and control water meters), new investigation should be organized with specific purpose to analyse the influence of service pressure on the demand and losses.

Another article (Nagib g. N. M., 2009) considers the application of a model predictive control (MPC) technique to improve the behaviour of the water network supply system, to maintain stable operation of the water flow rate, and reduce the operational cost by manipulating the pump speed.

Computer programs for modelling water supply systems are used around the world. The water supply system module in software package Mike Urban is developed on the basis of a computer program Epanet 2, created in U.S. This means that the designed water supply system model can be loaded in Mike Urban software package, because the programs are built using the same algorithm (Petr Ingeduld et al, 2006). So, Mike Urban is a modern water supply system simulation program. With this program we can analyse water distribution system at various operating cases, hydraulic shock conditions, water quality changes, not only during the period, but also a certain, user-defined period of time (Mitchell, V.G. et al, 2007).

The aim of research - to assess the capabilities of applying MIKE URBAN for optimizing the operation of water supply system in rural areas.

Object and Research Methods

Designed and analysed residential district water distribution network is in the Kaunas district municipality Domeikava, in settlement Radikiai (Fig. 1). Data for modelling was taken from UAB „Kaunas komprojektas“.
Before the water distribution network calculations are made with the computer program, the following basic input data is required: the largest hour drinking water discharge (l/s); the bottom elevation of wells (m); lengths of pipes (m), external diameter of pipes (mm), roughness coefficient (for determining head loss), ratios of minor losses; external diameter of air valve (mm), bottom elevation and elevation above some reference (m); external diameter of pressure relief valve (mm), bottom elevation and elevation above some reference (m); external diameter of non-return valve (mm), bottom elevation and elevation above some reference (m).

The elevation of sea level varies from 62.30 m to 77.00 m. The projected water distribution network covers 16.33 hectares. There are 445 residents living in Radikiai. Water consumption rates are given by Republican Building Standard (RSN 26-90, 1991). The water consumption rate is adjusted to the small town category and plumbing perfection. Radikiai belongs to the sixth category of cities and towns, and centrally will only be supplied with cold water. In this case, the relative water consumption rate per user is 160 l/d. Object maximum daily flow rate is calculated according to the usual water distribution network design formulas used in the RSN 26-90. Thus, the maximum daily flow is 106.05 m$^3$/d, the maximum hourly flow rate - 16.3 m$^3$/h.

Modeling process is a repeated set of algorithm that restores the flow of water in the system solutions. The program with set precision solves the set of equations, which define some basic flow water distribution network principles: the sum of inflow to the node and outflow must be equal to zero (first Kirchoff's law); the sum of head loss in any network loop must be equal to zero (second Kirchoff's law); total flow rate must be equal to the flow rate of nodal (nodal water balance rule) (Pekus R. et al, 2005).

In the software Mike Urban, hydraulic equations are used for calculating the flow rates in each pipe and head loss. The nodal flow rates are calculated by Method of reduced pipe length:

$$q_{pi} = \frac{(Q)l_{ij}}{\sum(k_{ui}l_{i})}$$  \hspace{1cm} (1)

where: \(Q\) – maximum daily flow rate of the object, l/s;
\(l_{i}\) – the length of pipe, m;
\(k_{ui}\) – the coefficient of node flow demand.

Minor head losses are due to local barriers, where flow is changing direction, velocity and the distribution of flow: bends, valves, enlarges reducers. Minor head losses are computed by formula:

$$h_{M} = \frac{0.0252Kq^{2}}{d^{2}}$$  \hspace{1cm} (2)

where: \(d\) – pipe diameter, mm;
\(K\) – the coefficient of minor loss, which depends on the barrier network;
\(q\) – flow in the pipe, l/s;

Head losses are calculated by formula:

$$h_{L} = aq^{b}$$  \hspace{1cm} (3)

where: \(q\) – flow in pipe, l/s;
\(a\) – coefficient of proportionality;
\(b\) – exponent, depending on the flow regime.

Pumps are described by pump performance curves. This curve is structured to refer to the relationship between pump head and efficiency. The pump curve can be plotted by introducing a characteristic pressure and high-performance point or introducing three characteristic points. The program creates the pump curve using the entered
data. The program can simulate several types of pumps according to user preference. The pump chosen in this project is created by a characteristic point on the pump curve by entering the required pump pressure head and efficiency, according to which the program creates the pump performance curve (Figure 2).

Figure 2. The pump curve drawings according to one characteristic point

Water level change in the tank is calculated by the following formula:

\[ \Delta y = \frac{q}{A} \Delta t \]  

where:\n- \( q \) – low flowing into (+) or from (-) reservoir, l/s;  
- \( A \) – reservoir area, m²;  
- \( \Delta t \) – the time interval, s; (DHI SOFTWARE..., 2007)

Due to the limited size of article, no other equations used in simulation algorithm, are discussed, because it is not pointed out in research aims.

To make a long-term study it is necessary to create a water consumption schedule, with water use percentage distribution of individual hours. The largest consumption of water is in the morning hours, so from 7 to 10 am indicated factor 1. During other hours of water use lower rates per unit are recorded because at other times, on the basis of long-term monitoring data of water supply systems, water consumption is lesser. This schedule indicates the variation in water consumption during the day and, after modeling, designer can analyse the water flow dynamics in nodes (Fig. 3).

Figure 3. The schedules of water consumption in Radikai

To investigate water quality a long-term study is selected. A three-day simulation period is selected to model water age. For that reason timing parameters are selected: duration of the study - 72 hours, the time step of hydraulic calculations - 1 hour, the time steps of the calculation of results - 1 hour, and the time step of water quality – 1 hour.

The study can be viewed in the simulation results, uploading the wanted results of such a layer: nodal flow rates, line discharges, water quality, pressure and so on, which are color-coded. Long-term results are clearly visible in the plot diagram for water animation. In animation settings it is necessary to define the animation start and end time in hours and animation interval.

The calibration can only be performed on functioning water supply system. The newly designed system cannot be calibrated because there is no real water supply system performance measurement data. In order to calibrate the existing water supply system it is necessary to have data on the pressure and flow rate at characteristic points of the system (not enough to have only the pressure data or only flow data). The most accurate calibration is obtained by
hydraulic head loss. Calibration is compared by the measured values with the simulated and the resulting percentage of difference between them and then observed what happens in the simulated system when any size is changed (Epanet2., 2000).

Results of Research

The program automatically calculated nodal flow, indicating a maximum flow rate of drinking water needs. Designed water network scheme with the calculated pressure head nodes is shown in figure 4.

![Designed by Mike Urban water distribution network in Radikiai and calculate the height of the pressure nodes](image)

Simulation showed that water supply network got too much pressure - from 111 to 136 m. According to STR (2.07.01:2003) requirements the pressure cannot be higher than 6 bar (61.855 m). Over- or under-pressure problems in the water supply system may be not only due to a line in diameter, but also due to improper pump head or performance selection. If the head does not fall or do not rise to the required standards then it is necessary to reduce or increase pipe diameters. Pump performance increase is the cheapest method to raise the pressure in the network, but the increase in performance of the pump higher pressure head can cause water hammer, especially when there is no pressure relief valve. Another possibility to solve the problem of high pressure is to build main pipelines at higher sites in the area.

In case of Radikiai water velocity \(v\) is low and the maximum 0.48 m/s is in pipe No. 65th. Water distribution system has been designed to be appropriate to fire-fighting, pipelines of 110 mm diameter (according Construction Technical Regulation STR 2.07.01:2003) were selected. This diameter is much too large for daily use flow nowadays. If water velocities in pipes with larger diameter decrease, the pressure head loss decreases too. For example, in branched network of 110 mm diameter pipe has \(v = 0.037\) m/s at a height loss of 0.027 m, reduction of the same pipe diameter up to 63 mm has \(v = 0.044\) m/s, and the head loss 0.049 m; reduced diameter up to 40 mm has \(v = 0.074\) m/s, and the head loss of 0.0863 m. In network places where piping diameters are smaller, the head is much higher, so if there is a high pressure problem in the system, one of the solutions is to increase the pipe diameters. With the increase of the diameter of the pipe the flow velocity decreases, thus reducing the energy requirement for water supply system. And vice versa, reducing the diameter of the pipeline due to the increasing water velocity increases the pressure loss in it, and hence the energy requirement. Determining pipeline operating costs take into account the fact that the greatest part of the electricity consumed in the supply of water.

As one of the measures installing of pressure-reducing valve was chosen to reduce excess pressure head and the changes in water distribution system were simulated. Pressure relief valve, inserted in the pump system did not reduce the high pressure.

When the pressure relief valve is in the lower location of network, the pump, with a capacity 2.74 l/s, maintains a slightly higher pressure and the power consumption is higher. Pressure, which supports the pump combined with the pressure relief valve in the current situation, is sufficient. Because the investigated water-supply system is a small, designing an uneven performance pump is more cost-effective. This pump should supply the required amount of water into the reservoir at night when electricity is cheaper. When steady operation pump cause a less water content compared with the calculated design, for example, minimum hours of use, then the result of high-pressure conditions in the installation height of the form. Therefore, the best solution would be to just install uneven performance pump. Non-return and shut-off valves must be installed in the pump pressure pipe. Single-impeller centrifugal pump is selected from the company Wilo catalogue.
When calculating the water network capacity in case of fire, it is checked whether water consumption during maximum extinguish a fire that broke out at the critical point of the No. 56, which is the highest and farthest from the pump in place is sufficient. Required amount of water produced at the critical point of water consumption plus the required fire fighting water. The operation of fire pumps in fire place must be maintained for at least 1 bar (10.3 m) pressure. Pressure high enough in critical point No. 56 to fully comply with the minimum requirements of high pressure supported 38.18 m. (Figure 6).

Pressure in the network in case of fire during the peak water consumption hours is sufficient - from 31.35 m in node No. 66 th to 41.76 in node No. 34 th. The maximum allowable pressure, which is up to 6 bar (61.855 m) in the network, is not exceeded. Because of fire leaking higher flow rates, the selected pump for normal use is no longer appropriate because not supported by the required minimum pressure of 1 bar fire. In case of fire, one working and one back-up pump must be installed. Therefore is selected fire pump, with a capacity - 5.5 l/s. Pump day working electricity costs about 25 Lt, but a fire to be extinguished three hours, and thus electricity costs could reach up to 3 Lt on the average in 2013 companies for electricity tariff. In the event of a fire, the water supply pumps used daily are turned off. If the system is low flow during a fire, then one would assume that the main line diameters too large, wrongly selected pump, fire starts far away from the water source or the system is shut down valves. In line No. 55 flowing with emergency flow head loss 1.66 m, and in normal case - 0.81 m. Head loss as low as 0.0009, the line number No. 14 (near the pressure relief valve), and the highest in lines No. 53 and 54, at the point where there is a simulated fire, to 33.53 and 33.46 m. Water velocities at the fire place and a significant increase to v = 1.0 m/s but not exceeding the maximum allowable fire (3 m/s). When fighting fire, flowing water discharges in bigger quantities, water velocity increases, leading to the formation and larger head loss. If the velocity of fire is too large, then there is one solution - to increase the diameter of the pipe. As in the test network velocities are not very high, network diameters can be chosen smaller, the performance and reduce costs, but also in accordance with the requirements of STR 2.07.01:2003 diameters may not be reduced, shall be 110 mm in diameter.

Figure 5. Results of water supply system operating at maximum water consumption (fragment)
Using Mike Urban software there are possibilities calculate water age in network. This is an important factor in determining the quality of water at the user. The increasing of water age in network increases chemical reaction time, which results in greater amounts of pollutants that may affect human health. Over the past 10 years water consumption decreased more than three times, therefore water transfer time from the source to the consumer increased, as well as water velocity in the network slowed down. During the first hour of the simulation water is more stagnant in branching network and it takes from half to one hour. During the second hour of the simulation, the water stagnates in branched network ends (from one to two hours). It is obvious that the loop network is superior to the branched: in lines of branched network the water is stagnant and simultaneously the water quality deteriorates. During the third simulation hour stagnation of water at the pressure relief valve and line for this valve (No. 15) was observed - the water stagnated here from two to three hours. During the fourth simulation hour water at pressure relief valve stagnates longest (more than four hours (Figure 7).

During simulation period of three days water age in the network does not change from the 4 hour of day one. If the population is supplied with chlorinated water, water stagnation time strongly influence the quality of the water. If water is stagnant in pipes longer, chlorine decreases as it decomposes over time. In this case conditions for microorganisms are becoming better. That alter the bad water smell, taste, color and deteriorate water quality.
In Lithuania the stagnant water problem is not spotlighted nor in hygienic norms HN 24: 2003, nor in Drinking water safety and quality requirements”, nor in STR 2.07.01:2003. There are no requirements to design water distribution network seeking to reduce the time of water stagnant. Use of software enables to optimize operation of water distribution system and to decrease water age. It was observed that water age in small water distribution systems decreases by increasing the pump pressure. In other systems, the age of the water can be reduced by adjusting the pressure zones, the choice of the optimal pipe diameters (in the large diameter pipeline slower flowing water, why water stagnation time is longer), or by optimizing water mixing in the tank (Effect ..., 2002).

**Conclusions**

Software Mike Urban opens many opportunities for properly modeling of water distribution systems. This allows for more efficient design, testing and management of water distribution system for controlling water quality, ensuring compliance with EU directives. Analyzing water supply network performance by Mike Urban program, as in case of Radikiai village residential area, creates the ability to optimize water pump operation at the lowest energy consumption and operation cost. In case of Radikiai, simulation of water supply network operation in the event of fire proved that network operation becomes disrupted due to insufficient capacity at the pump. As the solution an additional fire pump with capacity of 5,5 l/s were suggested.

Water quality simulation showed that there are areas where water is stagnant. This may cause the increasing of microorganisms that alter bad water smell, taste, and color and affects the quality of water.

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