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FOREWORD

The four independent reviewers estimated each paper and recommended 78 articles for publishing at the proceedings consisted of 2 volumes, which started life as presentations at the Annual 20th International Scientific Conference "Research for Rural Development 2014" held at the Latvia University of Agriculture, in Jelgava, on 21 to 23 May 2014.

In the retrospect of four months later, we can count the Conference as a great success. The theme – Research for Rural Development - attracted participation more than 150 researchers with very different backgrounds. There were 123 presentations from different universities of Lithuania, Estonia, Italy, Poland, Iran, Ukraine, Hungary, Czech Republic, Kazakhstan and Latvia.

Thank you for your participation! I'm sure that you have learned from the presentations and discussions during the conference and you can use the outcomes in the future.

The cross disciplinary proceedings of the Annual 20th International Scientific Conference "Research for Rural Development 2014" (2 volume since 2010) are intended for academics, students and professionals. The subjects covered by those issues are crop production, animal breeding, agricultural engineering, agrarian and regional economics, food sciences, veterinary medicine, forestry, wood processing, water management, environmental engineering, landscape architecture, information and communication technologies. The papers are grouped according to the sessions in which they have been presented.

Finally, I wish to thank Organizing and Scientific Committee and the sponsors for their great support to the conference and proceedings.

On behalf of the Organizing Committee

of Annual 20th International Scientific Conference

"Research for Rural Development 2014"

Ausma Markevica

Latvia University of Agriculture

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FORESTRY AND WOOD PROCESSING

ECONOMICS

USE OF FOREST BASED BIOMASS FOR BIOENERGY IN EU-28

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Abstract
Europe's future wood demand for energy is expected to increase by 10 million to 200 million m^3 in the period 2010-2030. This will be supplied by both domestic sources (forests, industrial residues post-consumer wood waste), but also from sources outside Europe. The EU-28 predicts a near future (2020) gap between solid biomass supply and demand for renewable energy: 21.4 million tonnes of oil equivalents (MTOE). This is estimated via preliminary renewable energy action plans (NREAP's) per country. The EU-28 expects wood pellet import will merely complete this gap of 21.4 MTOE, with more than 50 million tonnes of pellets. This implies a feedstock need of 125 million m^3 of wood from forests and other sources outside the EU-28.
A practical approach to include bioenergy in wood sector models should start with the input of wood pellets. Ideally, three types of bioenergy markets should be considered, in which pellets and the other major woody feedstock are included: 1. Large scale power production (the UK, Belgium, the Netherlands, all importing pellets from outside the EU-28); 2. Medium scale combined heat and power (CHP's) including those in the forest sector (Nordic countries use pellets and chips for energy, merely imported from the EU-28); 3. Small scale residential heating (Germany, Austria and Italy, using wood pellets and logs from regional sources). We suggest starting with inclusion of medium scale CHP's, followed by large scale power production. Small scale heating is relatively stable and should not have large impacts on future markets.
Key words: European forests, wood products, bioenergy, bio-economy, EU Forest Strategy, supply and demand model.

Introduction

As renewable energy sources (RES), forest biomass and other biomass provided about 10% (54 EJ equivalent with 1,300 MTOE) of global total primary energy demand (TPED) in 2011. This is supplied by about 3,100 million dry tonnes of biomass, equal to 7.5 billion m^3 wood and other biomass (Note: 1 EJ = 23.9 MTOE and is equivalent with 57 million tonnes of wood pellets or 138.5 million m^3 with moisture content of 20%). In 2011, traditional use of wood, straw, charcoal, and manures for cooking, space heating etc. in buildings accounted for about 64%. Another 15% occured in industrial sectors, like the use of pulp waste (black liquor) in the paper industries. Biomass use for electricity and transport fuels was 5% and 6% respectively. The remaining is estimated at about 6% (IEA 2013). Total future demand for bioenergy across all those global sectors is expected to increase from 54 EJ in 2011 to about 78 EJ in 2035, which is about 11% of the future TPED. This is referred to as the IEA's New Policies scenario (which is in between a current policies scenario and a '450 ppm' scenario with high renewable energy use). The largest proportion of demand for bioenergy is related to the building sector, including traditional use. This will decline in absolute terms throughout 2011-2035 (*Outlook* period). Driven by government support policies, the demand by the transport sector grows at the fastest rate over the *Outlook* period. The feedstock for those liquid biofuels is primarily covered by agricultural sources. The demand for bioenergy for power and heat generation has the largest increase, from 5.7 EJ in 2011 to 17.6 EJ in 2035 (Figure 1). Assuming that this type is merely covered by woody biomass (i.e., biomass with 20% moisture content), the increase equals to about 1,650 million m^3 wood.

According to the IEA forecasts, the demand for bioenergy increases significantly in the power sector in developing countries such as China, India and Brazil. This growth is mainly driven by policies to reduce air pollution, boost the use of domestic agricultural residues and speed deployment of renewables. Over 90% of the world demand is met from domestic resources throughout the *Outlook* period. To meet the remaining demand, some regions will increasingly turn to international supplies of solid biomass for power generation, most commonly in the form of wood pellets. Wood pellets are processed products that have a relatively high energy density, are fairly uniform and easier to transport than untreated biomass feedstock. A few regions are expected to supply any external needs, next to their domestic demand. Brazil, Canada and the United States stand out in this group, but also their natural resources are limited. For other regions, it will be difficult for the domestic supply to keep pace with the growing demand. In the New Policies scenario (IEA 2013), the European Union already imports large volumes of wood pellets and will continue to do so. The EU-28 is expected to be the largest importer of biomass for power generation by 2035, importing about 6.7 MTOE or 16 million dry tonnes biomass, equivalent with almost 40 million m^3 harvested wood. In India, the demand for solid biomass in power generation reaches 1.5 EJ, almost three times the current level, and requiring 90 million tons of pellet equivalents. While a similar

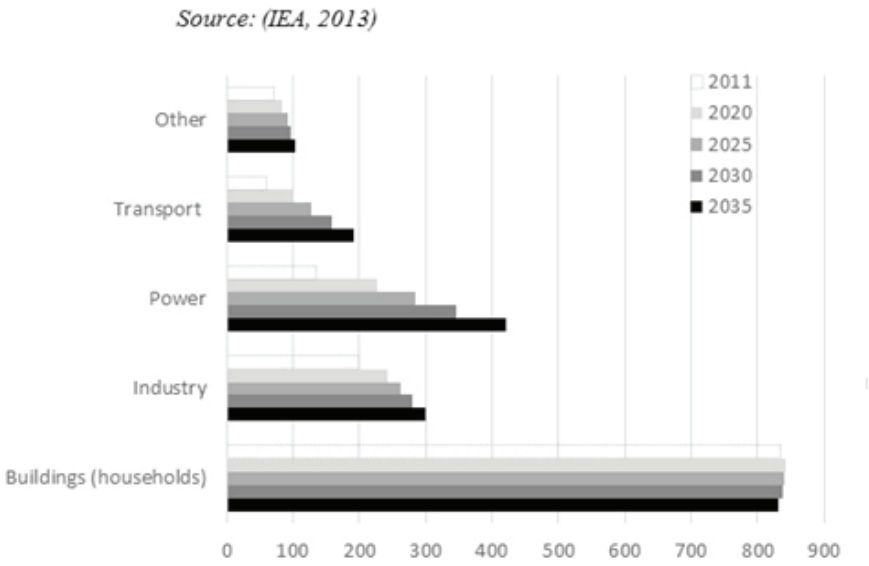

Figure 1. World bioenergy use by sectors in the New Policies scenario – in MTOE (IEA 2013).

order of magnitude of agricultural residues is available, it will be difficult to collect and transport them to the Indian power plants at reasonable costs. As for many fuels in the power sector, China will become the largest consumer of biomass for power generation and heat by 2035. It also has one of the highest supply potentials, when agricultural, and forest biomass are combined (IEA 2013).

So far, wood sector models merely lack a full picture of the growing future bioenergy demand. The main aim of this paper is to inventory which approach(es) to integrate energy in wood sector models are interesting and promising.

Materials and Methods

Approach to include bioenergy markets

In autumn 2013, the European Commission adopted a new EU forest strategy which responds to the new challenges facing forests and the forest sector (European Commission 2013). The strategy highlights that forests are not only important for rural development, but also for the environment, especially biodiversity, for forest based industries, bioenergy and in the fight against climate change. The new strategy underlines that forest-linked EU policies should fully be taken into account in national forest policies. It calls for a Forest Information System of Europe (FISE) to be set up and for Europe-wide harmonized information on forests to be collected. Within FISE, the Joint Research Centre (JRC) is setting up a Forest-based bio economy modelling framework (see Figure 2), for policy impact analysis that will be capable of addressing policy relevant issues and EU targets affecting the Forest Sector (EUTR, LULUCF, biodiversity, renewable energy, etc.). The framework should allow the assessmets of: i) market dynamics, not the least the competition for wood and energy uses; ii) response analysis, i.e., the impact on Europe's forest resources of different EU policies and targets. Actually, two types of wood models will be integrated: iii) the future supply of forest biomass, together with industrial residues and post-consumer wood; iv) the future demand by the traditional forest industries and the energy sector.

Next to the traditional forest-industry sector, the bio-energy sector is the main user of woody biomass. Following an extensive European inventory on wood markets for energy (Sikkema et al., 2011), inclusion of the bioenergy market can best be approached via their different market segments (Figure 3) 1. large scale power production (mostly industrial wood pellets, next to post consumer wood waste); 2. medium scale combined heat and power (CHP) (mostly wood pellets and wood chips); 3. residential heating (mostly wood pellets and low quality logs). Note that EU's 2010 Communications (European Commission 2010) about a framework for solid biomass for energy (including wood) is directing towards energy installations with a minimum capacity of 1MWth (heating) and 1 MWe (power) respectively. As such, large scale power and medium scale CHP's are above this limit and as such could be to future sustainablity requirements for woody biomass sourcing.

Large scale

Most of the large scale cofiring of biomass in Europe depends on feed-in tariffs for electricity production (Mir-Artigues and del Rio, 2014). Feed-in tariffs guarantee a certain price for produced kWh electricity. If the prices are low, the utilities will be

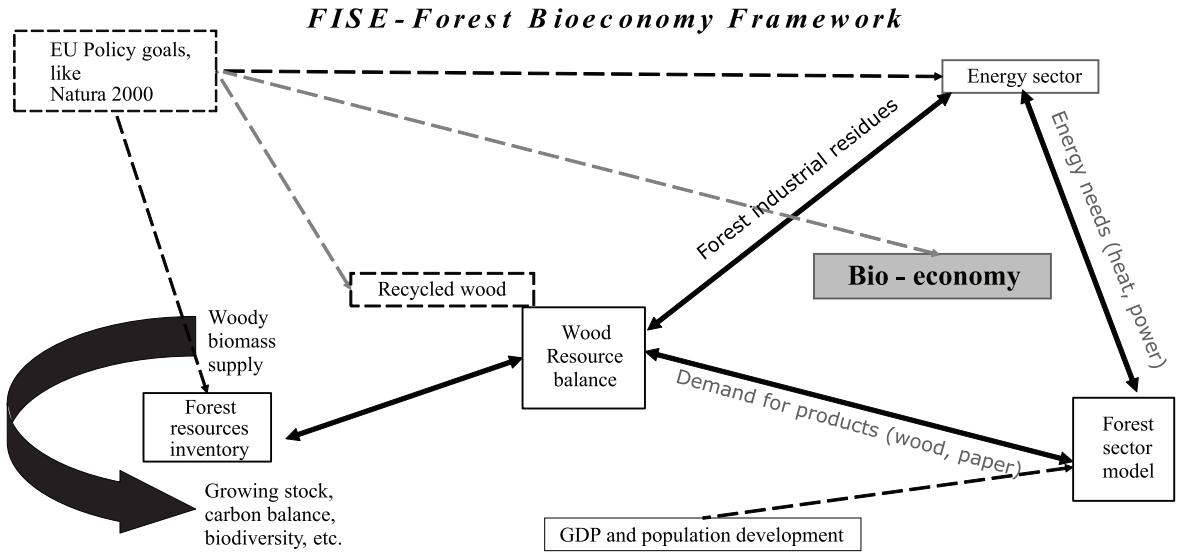

Figure 2. The JRC model for European forest biomass supply and demand.

refunded by public funds etc; with high prices, the utilities will have to pay the surplus to the public funds. It is not yet clear whether feed-in tariffs will remain. At least environmentally or economically harmful subsides, including for fossil fuels, are expected to be phased out (Client Earth, 2014).

The Pöyry modelling (Mergner 2014) has designed demand and supply curves for wood pellets. However, this modelling effort is not publicly documented and cannot be consulted. Also, the modelling approach regarding the solid biomass trade in Northwest Europe (Lamers et al., 2014) is relevant, however, the market analysis consists of both woody and agricultural biomass sources, mixed together in one model. The economic viability for cofiring in Germany has been evaluated, following price scenario's for biomass, coal and CO_2 certificates (Lüschen and Madlener, 2013). The economic feasibility of biomass co-firing will depend on relative cost of coal and biomass and CO_2 emission certificates (Hansson et al., 2009). However, this kind of modelling lacks the existing feed-in tariffs for electricity, a common financial structure for the energy sector in Northwest Europe.

Finally, the analysis of the Global Biosphere Management model (GLOBIOM) is of interest. GLOBIOM is a partial equilibrium model, dealing with the forest and the agricultural sectors (Lauri et al., 2014). Also, the energy production markets (demand) are incorporated to some extent. This model explicitly considers the competition between alternative uses of woody biomass through the market mechanism. However, it includes complex interactions of supply and demand, which makes the model less transparent compared to other models that consider woody biomass use for energy in terms of different (theoretical, technical, sustainable) potentials.

Medium scale heating and power production (CHP's)

Also, medium scale CHP's (like those established by forest and paper industries) are more or less depending on feed-in tariffs for any surplus of electricity production. Feed in tariffs should guarantee a certain price for produced kWh electricity, which is not needed for their own needs. Note that these feed-in tariffs are generally determined by the power utilities. For using their electricity distribution networks, the feed-in may be subject to relative low prices (in comparison with consumer prices). In case of district heating, owned by power companies or by municipalities, other feed-in tariffs are applicable, depending on the kind of (long term) contracting.

Different principles are valid for the delivery of any heat surplus, as this type of energy (e.g. steam) is transported within a limited distance to nearby customers (in case of public CHP's) or via bilateral contracts to neighboring intensive industries.

Further, the approach to include energy in a forest sector model, as done by EFI-GTM (Moiseyev et al., 2011; Moiseyev et al., 2013) is of interest. It has inserted woody feedstock data for medium scale heating and electricity production throughout Europe. Next to the traditional demand by the European forest sector (production of sawnwood, poulp, paper, panels), one overall energy sector is regarded. However, Moiseyev et al., (2013) did not analyze any feed-in tariff (*for surplus electricity*), due to the incompatibility with their partial equilibrium model. As the feed-in tariffs structure is out of scope, the EFI-GTM is at least not compatible for future elecricity markets and possible

carbon trading (see also section 3.1). The EFI-GTM model assumes the demand for thermal electricity and heat to be inelastic. Following the World Energy Outlook scenarios, the demand for electricity is not inelastic, but will increase between 2011 and 2035. In a similar way, the US modeling of the forest sector is set up (Zhang et al., 2014), although it has another division by including the transport sector, too: i) fuelwood; ii) transportation fuels; iii) electricity and heat.

Further, the global Forests Product Model or GFPM (Raunikar et al., 2010; Buongiorno et al., 2011; Buongiorno et al., 2012) is dedicated to energy markets. However, its price inventory is limited to two types of feedstock: fuelwood, and pulpwood (also defined as industrial round wood) and one type of final product: sawn wood. However, the GFPM modeling is a market simplification by aggregating all fuelwood into one bioenergy market.

Finally, three smaller, more regional, models have been developed. The first study focuses on Germany, and is based on the fuel price for oil (Härtl and Knoke, 2014). The competition with oil is valid for medium scale heating, although most conversion of oil based installations to wood fired installations occurred in the past (at least in most EU member states). Competition of wood with natural gas, rather than oil, will become valid for future developments due to increasing supplies by Russia. In the long term, it can be expected that EU dependency on gas from Russia and the Middle East will increase, which to a large extent will be utilized for power and heat generation (Kjärstad and Johnsson, 2007; Kjärstad, 2011). The second study (Schwarzbauer and Stern, 2010) focuses on Austria: it exists of a simulation model (FOHOW) to analyze the competitiveness between traditional demand for wood by the forest sector and increasing demand for energy by the same forest sector. Any external sector (energy sectors) is not integrated into the model. Again the oil price is inserted as the only feedstock for energy. This may not be applicable for further future, because natural gas shall operate as the main competing fuel.The third study focused on Norwegian forest sector (Bolkesjö et al., 2006). This Norwegian study has the same characteristics (partial equilibrium model) as the EFI-GTM. The advantage of this model is the inclusion of commercial electricity prices, both for large scale consumers and small ones. However, this kind of price may not be applicable, as forest industries will generally receive a lower price for any surplus of electricity. Nevertheless, this model may be relevant to be analyzed as well, as both small scale and medium scale users are included, varying from forest industries to external CHP's.

Small scale residential heating

It is expected (Esteban and Carrasco 2013) that the number of small heating appliances (capacity lower than 60 kW) in the EU-28 will grow by about 11% (from 4.9 million to 5.5 million boilers), with a major shift from wood chip boilers to pellet boilers. Note that small scale stoves (used for pellets in bags) are left out of this survey. With an average annual pellet consumption of 5 to 6 tonnes for small pellet boilers in Austria (personal communication with Holzforschung Austria), the impact on supply and demand modelling for EU's markets in 2020 is assumed to be fairly limited (increase by 3 million tonne).

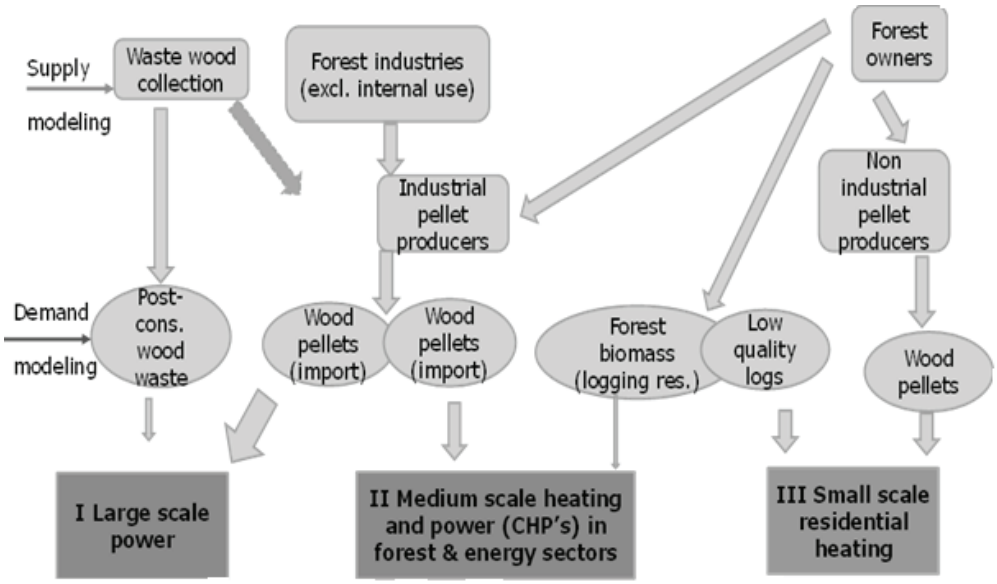

Figure 3. Division on EU's bioenergy sector in three major markets.

Results and Discussion

The impacts of a growing need for wood for energy, combined with the traditional demand by the forest industries are compiled in global forest product models (Raunikar et al., 2010; Buongiorno et al., 2011; Buongiorno et al., 2012). The GFTM study is linked to the projections of the Intergovernmental Panel on Climate Change (IPCC) for high energy use (maximum fuelwood demand) and low energy use (minimum fuelwood demand) respectively. The maximum fuelwood demand, together with a nearly steady demand for industrial roundwood, leads to a total annual roundwood consumption from 3.55 billion m^3 in 2006 to about 4.96 billion m^3 in 2030, thus, an extra demand on a global scale by about 1,400 million m^3. The economic and demographic assumptions coupled with a scenario of low fuelwood demand, lead to a global harvest of 3.70 billion m^3, thus 150 million m^3 extra. The share of Europe in these consumption patterns (industrial wood and fuelwood together) is expected (Buongiorno et al., 2012) to increase from 645 million m^3 in 2006 to a level of 663 million m^3 (minimum demand) and to 859 million m^3 in 2030 (maximum demand). The sub share of industrial roundwood remains stable. Resuming, EU's demand for energy wood is expected to increase from a level of 145 million m^3 to about 155 million m^3 (low demand) to more than 360 million m^3 (high demand), an increase by 10 million to 200 million m^3 of wood (about 5 to 120 million dry tonnes).

The current share of virgin wood (from forest and forest industries) and wood waste in EU's gross energy consumption (GEC) in 2011 is 3.4 EJ, i.e. 4.8% of total GEC (Eurostat 2012). This is equal to about 195 million tonnes of dry wood with an energy value 17.5 GJ per tonne. The EU Renewable Energy Directive (RED) strives for mobilisation of domestic and imported biomass (including wood) via EU Member State's National Renewable Energy Action Plans (NREAP's). The preliminary NREAP's indicate a total biomass supply (forest, agriculture and waste) starting from 88 MTOE in 2006 to about 131 MTOE in 2020 (Banja et al., 2013). The increase for virgin wood fibres from forests and forest industries is about 11 MTOE or 25 million tonnes (equal to about 45 million m^3). The preliminary NREAP's indicate a growth for wood waste flows of about 4.5 MTOE, equal to about 11 million dry tonnes of post-consumer wood waste. The NREAP gap between supply and demand of biomass within the EU-28 is estimated to be about 21.4 MTOE (0.9 EJ) and expected to be merely completed by wood pellets (DG Energy, 2014). This would implicitly mean an import of about 51 million tonnes of pellets. For comparison: an inventory by the European energy sector (Eurelectric, 2011), stated a relative large import by the EU-28 of about 55 million to 85 million dry tonnes of wood is likely to be needed for meeting EU's future annual wood demand for heating and electricity in 2020.

All partial equilibrium models depart from the notion of perfect competition, this is, of course, a shortcoming, but one has to deal with it when modelling energy, just as for the traditional wood-based commodities. The state-of-the-art of bioenergy markets (2010) in Europe can be compiled from basic data by (Hendrickx 2010; Mantau 2012; CEPI 2013; Sikkema et al., 2014). For EU-28, the following sub-division in 2010 is applied:

- Small scale residential heating: 91 million tonne
- Large and medium scale CHP's: 90 million tonne (including black liquor and chips by forest sector)
- Pulp industry feedstock: 70 million tonne
- Panelboard industry feedstock: 32 million tonne
- Sawmills: not yet specified, as there is no interference with energy related feedstock

For future data we suggest relying on the National Reneweble Energy Action Plans (NREAP's). These data are inserted by the Member States of EU-28, for reporting obligations. These obligations are completed via the National Renewable energy Action Plans for the period 2009-2020, like in (Banja et al., 2013). Note that the overview below is a preliminary one, as the data needed for the new modelling has still to be verified. Actually, two major markets of wood (and other) biomass need to be accounted for supply and demand markets.

Future supply of biomass (million ton of oil equivalents) is divided into:

- ✓ 2 forest resource categories (forests, forest industries), i.e. woody biomass
- ✓ 2 agricultural resource categories (agriculture, agricultural residues)
- ✓ 3 waste categories (note that post-consumer wood waste is a part of solid wastes)

Future demand of biomass (markets) is divided into 3 main categories:

- ✓ Biomass for electricity and heating except agricultural residues for co-digest / biogas in, for example, Germany, most biomass is related to woody biomass (pellets, chips, low quality logs)
- ✓ Biomass for heating and cooling; both biomass from forest and agriculture.
- ✓ Biomass for transportation fuels, merely existing of agricultural biomass

Conclusions

- Best practice approaches for including bioenergy markets in wood models are found for medium scale power and heating. Next to the worldwide approach (Lauri et al., 2014), the regional approach

for the United States (Zhang et al., 2014), EU-28 plus some other European countries (Moiseyev et al., 2011; Moiseyev et al., 2013) and Norway (Bolkesjö et al., 2006) are promising. All models are stated to be based on a partial equilibrium model, focusing on the short term wood markets but without any clear long term prospects for others (e.g. CO_2 trade certificates).

- A major point of concern is the lack of a feed-in tariff structure in the respective models (GLOBIOM; US-FPM; EFI-GTM; NTM-II). This structure is relevant throughout most EU Member States. It guarantees a certain purchase price per kWh, and this is also valid for the internal electricity production within the forest sector itself.
- Another point of concern is the inelastic demand for electricity (Moiseyev et al., 2011; Moiseyev et al., 2013). This does not comply with 2030 predictions for an increasing electricity use in comparison with current consumption patterns.
- Finally, the interaction of limited available future forest resources and increasing competition between traditional wood markets and the energy sector is a point of attention for integrated models.

References

1. Banja M., Scarlat N., Monforti-Ferrario F. (2013) Renewable energy development in EU 27 (2009-2010). JRC scientific and policy report (including background Excel files). Ispra, JRC. EUR 26166 EN.
2. Bolkesjö T.F., Trømberg E., Solberg B. (2006) Bioenergy from the forest sector: economic potential and interactions with timber and forest products markets in Norway. *Scandinavian Journal of Forest Research* (21): pp. 175 – 185.
3. Buongiorno J., Raunikar R., Zhu S. (2011) Consequences of increasing bioenergy demand on wood and forests: an application of the GFP model. *Journal of Forest Economics* (17): pp. 214 – 229.
4. Buongiorno J., Zhu S., Raunikar R., Prestemon J.P. (2012) Outlook to 2060 for world forests and forest industries: a technical document supporting the forest service 2010 RPA assessment. US Department of Agriculture, Washington, United States.
5. CEPI (2013) Key statistics European pulp and paper industry 2012. Available at: www.cepi.org, 29 September 2013.
6. Client Earth (2014) Paper of the services of DG Competition containin draft Guidelines on Environmental and Energy Aid for 2014 – 2020. Available at: www.clientearth.org, 24 February 2014.
7. DG Energy (2014) State of play on the sustainability of solid and gaseous biomass used for electricity, heating and cooling in the EU (SWD final). Available at: http://ec.europa/energy/renewables/bioenergy/sustainability_criteria_fr.htm, 28 July 2014.
8. Esteban L.S., Carrasco J. (2013) European residential biomass boiler outlook. *Bioenergy International* 7 (69): pp. 41 – 42.
9. Eurelectric (2011) Biomass 2020: opportunities, challenges and solutions. Available at: www.eurelectric.org, 17 November 2013.
10. European Commission (2010) Report to the Council and the European Parliament on sustainability requirements for the use of solid and gaseous biomass sources in electricity, heating and cooling. SEC 2010 final pp. 65 – 66.
11. European Commission (2013) The new EU Forest Strategy. Available at: http://ec.europa.eu/agriculture/forest/ strategy, 18 March 2014.
12. Eurostat (2012) Production and consumption of wood in the EU27. Available at: http://europa.eu/rapid/press-release_STAT-12-168_en.pdf, 29 November 2012.
13. Hansson J., Berndes G., Johnsson., Kjärstad J. (2009) Co-firing biomass with coal for electricity generation - an assessment of the potential in the EU-27. *Energy policy* (37), pp. 1444 – 1455.
14. Härtl F., Knoke T. (2014) The influence of the oil price on timber supply. *Forest Policy and Economics* (39), pp. 32 – 42.
15. Hendrickx B. (2010) Use of raw material by European forest sector. *EPF Annual meeting* (10 March 2010). Brussels, Belgium.
16. IEA (2013) Section 6 Renewable energy outlook. In WEO: *World energy outlook*. IEA, Paris, France.
17. Kjärstad J., Johnsson F. (2007) "Prospects of the European gas market". Energy Policy (35), pp. 869 – 888.
18. Kjärstad J. (2011) Chapter 22 Prospects for the European gas market. In: Johnsson F. E*uropean energy pathways; pathways to sustainable European energy systems*; Chalmer University of Technology, Gothenburg, Sweden, pp. 207 – 214.
19. Lamers P., Hoefnagels R., Junginger H.M., Hamelinck C., Faaij A.P.C. (2014) Global solid biomass trade for energy by 2020: an assessment of potential import streams and supply costs to NW Europe under

different sustainability constraints. *GCB Bioenergy*, Available at: http://onlinelibrary.wiley.com/doi/10.1111/gcbb.12162/abstract, pp.1 – 17.
20. Lauri P., Havlik P., Kindermann G., Forsell N., Böttcher H. (2014) Woody biomass energy potential in 2050. *Energy policy* (66), pp. 19 – 31.
21. Lüschen A., Madlener R. (2013) Economic viability of biomass cofiring in new hard-coal power plants in Germany. *Biomass & Bioenergy* (57), pp. 33 – 47.
22. Mantau U. (2012) Wood flows in Europe. Available at: http://www.cepi.org, 29 September 2013.
23. Mergner S. (2014) The dynamics of global pellet markets; growth prospects and price scenarios. *Fourth Central European Biomass Conference*, Graz, Austria. Poyry Management Consulting, Germany.
24. Mir-Artigues P., del Rio P. (2014) Combining tariffs, investment subsidies and soft loans in a renewable electricity deployment policy. *Energy policy* (69), pp. 430 – 462.
25. Moiseyev A., Solberg B., Kallio A.M.I. (2013) Wood biomass use for energy in Europe under different assumptions of coal, gas and CO_2 emission prices and market conditions. *Journal of Forest Economics* (19): pp. 432 – 449.
26. Moiseyev A., Solberg B., Kallio A.M.I., Lindner M. (2011) An economic analysis of the potential contribution of forest biomass to the EU RES target and its implications for the EU forest industries. *Journal of Forest Economics* (17), pp. 197 – 213.
27. Raunikar R., Buongiorno J., Turner J.A., Zhu S. (2010) Global outlook for wood and forests with the bioenergy demand implied by scenarios of the IPCC. *Forest Policy and Economics* (12), pp. 48 – 56.
28. Schwarzbauer P., Stern T. (2010) Energy versus material: economic impacts of a "wood-for-energy scenario" on the forest-based sector in Austria - a simulation approach." Forest Policy and Economics(12), pp. 31 – 38.
29. Sikkema R., Junginger H.M., van Dam J., Stegeman G., Durrant D., Faaij A.P.C. (2014) Legal harvesting, sustainable sourcing and cascaded use of wood for bioenergy: their coverage through certification frameworks for sustainable forest management. *Forests* 5 (9), pp. 2163 – 2211.
30. Sikkema R., Steiner M., Junginger H.M., Hiegl W., Hansen M.T., Faaij A.P.C. (2011) The European wood pellet markets: current status and prospects for 2020. *BioFPR* 5 (3), pp. 250 – 278.
31. Zhang S., Gilless J.K., Stewart W. (2014) Modeling price-driven interactions between wood bioenergy and global wood product markets. *Biomass & Bioenergy* (60), pp. 68 – 78.

SPATIAL ANALYSIS OF AFFORESTATION IN POLAND UNDER RURAL DEVELOPMENT PROGRAMME 2007-2013

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Abstract
The paper covers spatial analysis of the Measure "Afforestation of agricultural and other than agricultural lands" implemented in Poland within the framework of the Rural Development Programme 2007 – 2013 (RDP 2007 – 2013). Beneficiaries obtained payments for afforestation based on the commitments made during the programming perspective of 2004 – 2006 or they joined the programme during the perspective of 2007 – 2013. Data obtained from the Department for Direct Payments of the Ministry of Agriculture and Rural Development as of 31 December 2012 formed the base of the analysis. Payments made in the country to the beneficiaries considering their activity and absorption of funds within the framework of the measure are presented. Next, given the disbursements made in voivodships and counties of Poland, the activity of beneficiaries was indicated and average disbursements per beneficiary were determined. The analysis aims at investigating the consistency of the afforestation policy implemented in Poland as of 2004 and showing the role of afforestation projects implemented within the RDP framework. The aim of the article is to show spatial changes in the intensity and dynamics of agricultural land afforestation projects implemented within the framework of the RDP 2007 – 2013 considering natural conditions.
The afforestation rate and the ownership structure of the forestland in Poland is diverse. Afforestation allows and rationally manages agricultural land, which is of little use for agricultural production. The utilization of EU funds supporting afforestation of agricultural land in Poland is characterized by spatial variability.
Key words: Rural Development Programme, afforestation of land, afforestation rate, rural areas.

Introduction

Increasing the afforestation rate of the country is one of the major elements of forestry policy in Poland. In the past, as a consequence of socioeconomic processes, mainly increasing the area used for agricultural purposes, the afforestation rate of Poland decreased to 38% in 1820 and 20% in 1938. Consistent implementation of the goals of the afforestation policy accepted and implemented in Poland as of 1995 should assure increasing the afforestation rate of the country to 30% in 2020 and 33% by 2050 (KPZL, 2003).

Introduction of forest on non-forest land used for agriculture or representing temporary wasteland is referred to as afforestation (Płotkowski, 2008). The idea of land afforestation in our country appeared during the 19th c. The process was intensified after the World War II. Currently, around 30% of Polish forests grow on land that had been deforested and then used for agriculture or left waste (Szujecki, 2003). During the period of 1945 – 2000, the area of forests and lands related to forest economy increased from 6,470.000 ha to 9,059.000 ha, i.e. by 40.0%. During that period the afforestation rate of the country increased from 20.8% to 28.4%. The largest scope of afforestation projects was recorded during the 1960-s (even 60,000 ha a year were afforested) (Biczkowski and Głaz, 2012). Despite the earlier activities, the afforestation rate of Poland continues to be lower than the European average, which is 31.1%. The current afforestation rate of Poland is 29.3% (according to the Central Statistical Office data for 2012). Except Ukraine (afforestation rate at 17%), the other countries bordering Poland have higher afforestation rates (Byelorussia – 44%, Czech Republic – 34%, Lithuania – 36%, Germany – 32%, Slovakia – 40%). The rational afforestation rate of Poland, from the perspective of land use structure and environment development at the current civilisation development stage, should be 33 – 34% (KPZL, 2003).

Increasing the afforestation rate of the country and of its individual regions is consistent with international resolutions and treaties of which Poland is a signatory. It will serve accomplishment of the goals and environment status improvement formulated there (National Programme for Increasing the Afforestation Rate, 2003). Degradation of the natural environment is one of the major reasons for the necessity of implementing afforestation programmes both in Poland and other EU countries (Louwagie et al., 2011). As of 1 May 2004, Poland is a member of the European Union and the resulting necessity of implementing the principles of the Common Agricultural Policy (CAP) is tied to increasing the rank of areas with unfavourable natural conditions. The Common Agricultural Policy has been in operation since 1957, and it is a subject to continual reforms given the changing economic and international conditions (Upite and Pilvere, 2011). The EU CAP considers multidimensional correlations between the agriculture and the natural environment (Kołodziejczak and Rudnicki, 2012). Afforestation of agricultural lands is one of the measures serving accomplishment of that goal. It has been implemented within the framework of the Rural Development Programme 2004 – 2006 (RDP 2004 – 2006).

The measure had been continued within the framework of the RDP 2007 – 2013. Additionally, according to Schedule II, it had been continued as afforestation of non-agricultural land. Areas of fertility classes V, VI and VIz represent ca. 34% of the total area of agricultural land in Poland. Polish agriculture is characterised by an excessive use of land of low suitability for agriculture and the land exposed to erosion or other threats. Hence, afforestation of land is particularly important in case of Polish agriculture (Rudnicki, 2010; Biczkowski and Rudnicki, 2013). On the other hand, the involvement of Polish forestry in the development of marginal soils results, first of all, in the statutory performance of environment creating and public functions of forests. This applies mainly to the favourable influence of forests on the water balance of the country, limitation of erosion processes, preventing landscape changes into steppes, air, waters and soils cleaning of chemical substances, decreasing the greenhouse effect and improvement of living quality in urbanised areas (KPZL, 2003). As of 2005, an increased interest of farmers in agricultural land afforestation has been observed in Poland. This results from the possibility of afforestation financing within the frameworks of the EU Common Agricultural Policy. Moreover, farmers receive the afforestation bonus representing the compensation for income lost as a consequence of excluding land from agricultural use. The importance of environmental aspects in planning and implementation of afforestation works has been increasing. The public expectations related to taking into account the requirements of nature protection and landscape development as well as expanding biodiversity has also been increasing (Polna and Szczepański, 2010).

The aim of the study is to determine the preferences of beneficiaries implementing afforestation under the RDP. The analysis will identify barriers and factors affecting implemented afforestation of agricultural land in Poland. The question whether the Common Agricultural Policy assumptions and afforestation policy implemented within its framework represent an instrument efficient enough to attract farmers to agricultural land afforestation remains open. Farmers expect even more attractive funds for afforestation and only some of them are focused on temporary maximisation of profits in case of afforestation (Duesberg et al., 2013).

Materials and Methods

The paper aims at presenting the scale and spatial diversity in the use of funds for afforestation within the framework of the RDP during the years 2007 – 2013. Afforestation of agricultural and other than agricultural lands results in the permanent change of agricultural land (the least suitable for agricultural production) into forest. The national scale analysis was conducted. The regions (voivodships) and counties represented by 314 county offices of the Agency for Restructuring and Modernisation of Agriculture (ARMA) were assumed as the basic units. The analysis considered afforestation preferences resulted from the quality of soils, their spatial diversification and suitability of agricultural land for agricultural use. The current afforestation rates of the individual regions were also taken into account. The analysis of afforestation rates' change dynamics in counties during the years 2004 – 2012 was conducted too. In addition, the share of private forests was included in the total forest area. The appropriate measures were defined within the framework of the payments disbursed during the financial perspective of 2007 – 2013, which were as follow: the activity of beneficiaries in the individual counties and the amount of support received (in PLN).

The analysis was based on the data obtained from the Department for Direct Payments of the Ministry of Agriculture and Rural Development. The data covered the payments disbursed to beneficiaries that implemented the measure called Afforestation of agricultural and other than agricultural lands within the frameworks of the RDP 2007 – 2013 as of 31 December 2012. The Regional Databank data made available by the Central Statistical Office and also those contained in the yearbooks prepared by that Office were used for analyses. The assumptions of the National Afforestation Rate Increasing Programme by 2050 were the baseline for the analyses conducted.

Results and Discussion

Conditions of afforestation in Poland

Exclusion from agricultural use of lands representing low suitability for agricultural use and afforestation of such lands influence the sustainable development of agriculture and rural areas positively, both directly and indirectly. The direct influence is represented by increasing the forest areas and afforestation ratio, hence, creating conditions for strengthening ecosystems and biodiversity in rural areas. Indirectly, afforestation creates opportunities for additional employment, and it also generates the income for the rural population (Polna, 2011).

The quality of Polish soils is among the lowest in Europe. The natural conditions of Poland from the perspective of agricultural production are 30 – 40% worse than in the Western European Countries. The production potential of the average hectare of our soils corresponds to the potential of the average 0.6 ha of arable land in the European Union. Hence, rational soil resources management is the most important issue considering appropriate functioning of ecosystems and protection of highly productive soils (Skłodowski and Bielska, 2009; Jarský and Pulkrab, 2013).

Table 1

Key conditions of afforestation in Poland

Item	Afforestation rate (%)		Share of private forests in total forest area (%)		Agricultural production space quality indicators (points)	Agricultural land according to the fertility class		
	2004	2012	2004	2012		V (%)	VI (%)	VIz (%)
POLAND	28.7	29.3	18.4	19.4	66.6	22.6	11.4	0.8
Dolnośląskie	29.1	29.6	2.3	2.9	74.9	16.5	5.2	0.2
Kujawsko-Pomorskie	23.1	23.4	10.5	11.4	71.0	15.7	8.9	1.0
Lubelskie	22.3	23.1	39.0	40.5	74.1	16.6	6.4	0.4
Lubuskie	48.7	49.1	1.2	1.5	62.3	27.7	15.1	0.5
Łódzkie	20.6	21.2	32.3	33.7	61.9	30.1	16.1	1.2
Małopolskie	28.4	28.6	43.5	43.7	69.3	21.8	8.6	0.7
Mazowieckie	22.1	22.9	42.2	43.8	59.9	28.4	16.6	1.3
Opolskie	26.3	26.5	4.3	4.7	81.4	15.6	6.1	0.0
Podkarpackie	36.5	37.8	14.7	16.9	70.4	20.1	7.4	0.6
Podlaskie	29.7	30.6	31.2	32.4	55.0	29.5	17.6	1.4
Pomorskie	35.8	36.3	10.5	11.2	62.2	21.3	13.3	1.2
Śląskie	31.7	31.8	20.0	20.1	64.2	25.9	10.0	1.1
Świętokrzyskie	27.5	28.0	26.6	28.2	69.3	22.0	13.6	1.4
Warmińsko-Mazurskie	29.9	30.9	4.9	7.1	66.0	18.8	6.8	0.2
Wielkopolskie	25.4	25.7	10.2	10.7	64.8	25.6	16.3	1.0
Zachodniopomorskie	34.7	35.4	1.3	2.1	67.5	20.5	6.7	0.6

During the years 1946 – 2001, the afforestation ratio (computed as the ratio of forest area to total area of the country) increased from 20.8% to 29.2%. Still, it is lower than the ultimate ratio set for Poland at the level of 33 – 34%. To accomplish the intended objective in 2020, it is necessary to include almost 485,000 ha of post-agricultural lands (unsuitable for agricultural production) and wastelands in afforestation projects during the years 2012 – 2020. During the years 1995 – 2011, 262,000 ha were afforested (Concise Statistical Yearbook of Poland, 2012).

In 2012, the afforestation rate of Poland was 29.3%. Uneven distribution of forests within the area of the country as well as significant crumbling and dispersion of forest complexes represented a significant problem. The current afforestation rates for the individual voivodships of Poland are presented in Table 1.

The highest afforestation rate in Poland is found in Lubuskie voivodships at 49.1%. Significant afforestation is also characteristic for Podkarpackie, Zachodniopomorskie, Pomorskie, Śląskie, Warmińsko-Mazurskie and Podlaskie voivodships. At the same time, those voivodships have high shares of low fertility class lands (class V, VI and VIz). In Poland, the ownership structure of forestland in the regions is very diverse. In 2012, it varied from 1.5% in Lubuskie to 43.8% in the Mazowieckie voivodship. In the years 2004 – 2012, it is during the implementation of afforestation under the RDP when a very large increase in the share of privately-owned forests was visible. The highest growth was recorded in Zachodniopomorskie voivodship by 61% and Warmia-Mazury 44%. Significant increase in the share of private ownership in the forest structure confirms the large impact of the RDP on increasing afforestation rate in the country.

Table 1 presents also the agricultural production space quality indicators reflecting suitability of agricultural land for agricultural production. The regional diversification of agricultural production space in Poland results from spatial differences in soil coverage, land morphology as well as precipitations and temperature. It is expressed in points, and it is the sum of the individual elements. The average rate for the country is 66 points. It is worth highlighting that the lowest agricultural production space quality indicator value is characteristic for Podlaskie voivodship at 55 points. In the region of Podlaskie the share of the poorest soils is the highest one.

The areas preferred for afforestation are situated mainly along the northern and eastern border of the country. During the years of 2004 – 2012, according to the general balance, the increase of the afforestation rate occurred in all the voivodships of the country (Table 1).

The highest increase was recorded in 69 counties distributed mainly along the northern and eastern border of the country. The smallest increase was recorded in the counties of Wielkopolskie and

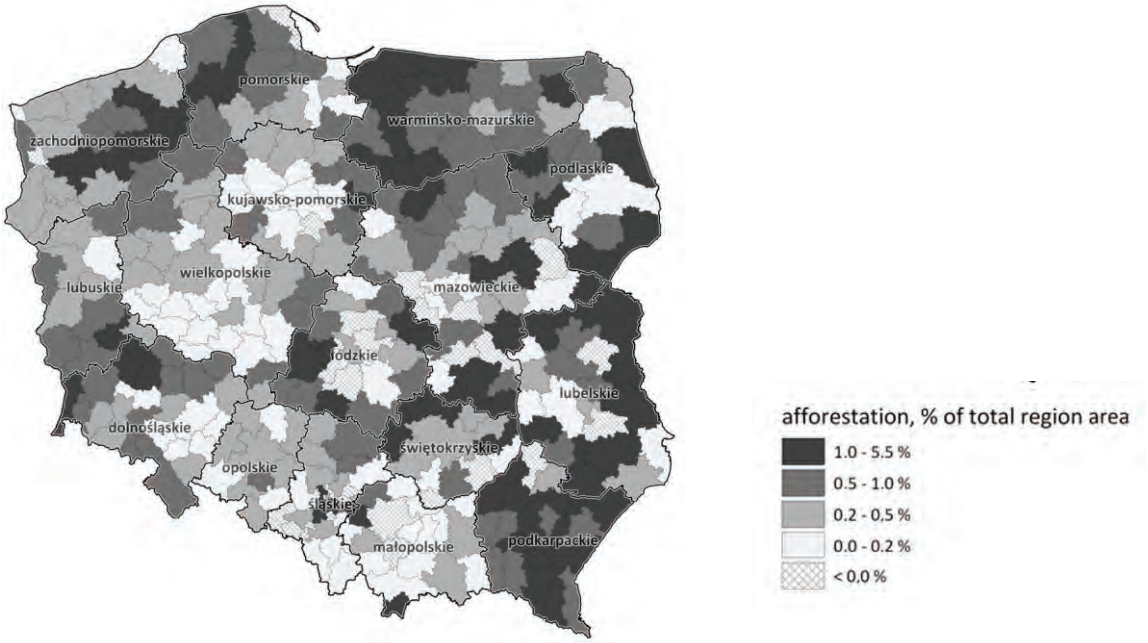

Figure 1. Dynamics of changes in afforestation rate in the counties of Poland during the years 2004 – 2012.

Małopolskie voivodships. It is worth highlighting that in 29 counties a slight decrease in afforestation ratio was recorded. That phenomenon is visible at most in Małopolskie, Łódzkie and southern part of Mazowieckie voivodship (Fig. 1). This is a consequence of allocating agricultural and forestland for uses other than agriculture and forestry.

Polish experiences in afforestation

Until accession to the European Union, a diversified system of afforestation works funding was in operation in Poland. The state-owned land had been afforested by the State Forests from the budget funds. The extent of afforestation works implemented depended significantly on the funds allocated each year for the purpose in the Budget Act. In addition to the budget subsidies, afforestation of private lands was supported from the funds of the Voivodship Funds for Environment Protection and Water Management and, to a marginal extent, from the State Forests funds in the form of free seedlings. During the years 2002 – 2004, the new system for agricultural land afforestation financing was applied based on the Act on allocation of agricultural land for afforestation. After Poland's accession to the EU, rural areas in our country became one of the major beneficiaries of the financial support system (Bułkowska and Chmurzyńska, 2011). Also, radical change in financing private land afforestation took place in Poland. Afforestation of agricultural lands is one of the measures included in the Rural Development Programme (Płotkowski, 2008; Polna, 2007).

Afforestation implemented within the framework of the RDP 2004 – 2006 was consistent with the National Programme for Increasing the Afforestation Rate (KPZL, 2003). It covered land that was not the property of the State Treasury. A farmer, a group of farmers (minimum 3 persons) or an agricultural production cooperative could be the beneficiary. Afforestation was carried on land that was qualified as agricultural land, including arable land, permanent green land, orchards and fruit plantations. Those land pieces should be under permanent agricultural use. They should also be classified mainly as fertility class V and VI and as land on slopes with inclination exceeding 12°. Afforestation of lands that lay idle or resting for longer than 5 years and wastelands were not covered. The share of class I-IV land should not exceed 15% of the area covered by afforestation. The farmer undertaking the activity was offered three forms of financial support. The first one was the support for afforestation represented by a single lump sum payment to cover the afforestation costs. The care bonus represented the additional form of support. It was a lump sum payment to cover the costs of maintaining the new forest plantation disbursed yearly for 5 years as of establishment of the plantation. The afforestation bonus was also a significant form of support. It aimed at balancing the income lost as a consequence of excluding land from agricultural production during 20 years as of establishment of the plantation. During the programming period of 2004 – 2006, no limitations for area afforested existed (RDP 2004 – 2006). The indicated criteria, however, were not respected fully.

Class I - IV land represented as much as 34% in the total area of afforested agricultural land (Drożdziel, 2007; Rudnicki, 2010). The RDP 2004 – 2006 budget for the measure: Afforestation of agricultural land was 2.71% of the total RDP budget (Bórawski, 2010).

Afforestation of agricultural lands within the framework of the RDP 2007 – 2013 was implemented according to two Schedules: Afforestation of agricultural lands (Schedule I) and Afforestation of lands other than agricultural (Schedule II – introduced as of 2008). Schedule II applies solely to forestry development of abandoned agricultural lands or the land left idle for which afforestation represents a reasonable method of development (e.g. protection against erosion). The use of natural succession within the above identified lands is assumed as a possible solution.

During the first stage of the RDP 2007 – 2013 implementation (until 2011), there was an area limit per one beneficiary (maximum 20 ha). Currently, the support for afforestation may be awarded to a single farmer for the area not exceeding 100 ha. Afforestation within the framework of the RDP 2007 – 2013 may not be carried out on land situated within NATURA 2000 areas, areas of sanctuaries of the nature, landscape parks, national parks of their protective areas unless the planned afforestation is in line with the goals of protection of those areas. One of the guidelines of the Regulation on detailed conditions and procedures for granting financial aid under the measure "Afforestation of agricultural land and afforestation of non-agricultural land" under the Rural Development Programme for 2007 – 2013 are determinants of planning (2001, No 48, item 390). Support for the afforestation of agricultural land is granted to the farmer of the land that has been designated for afforestation in local spatial development plan. In the absence of a plan for afforestation of agricultural land is not contrary to the findings of a study of conditions and directions of spatial management.

The principles of aid funds disbursement are identical as during the 2004 – 2006 period. However, the period of afforestation bonus was shortened to 15 years as of the forest plantation establishment. Farmers will obtain at least 25% of income from agricultural activity during the year immediately preceding lodging the application (RDP 2007 – 2013).

Afforestation projects implemented within the framework of the RDP 2007 – 2013

Within the framework of the measure of afforestation of agricultural land and afforestation of

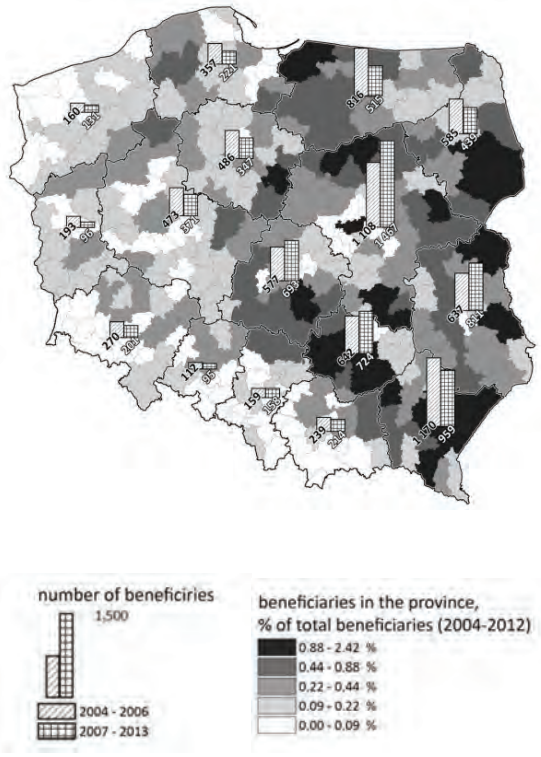

Figure 2. Activities of beneficiaries conducting afforestation and average disbursements per 1 application in the voivodship within the framework of the RDP 2007 – 2013 as of 31 December 2012.

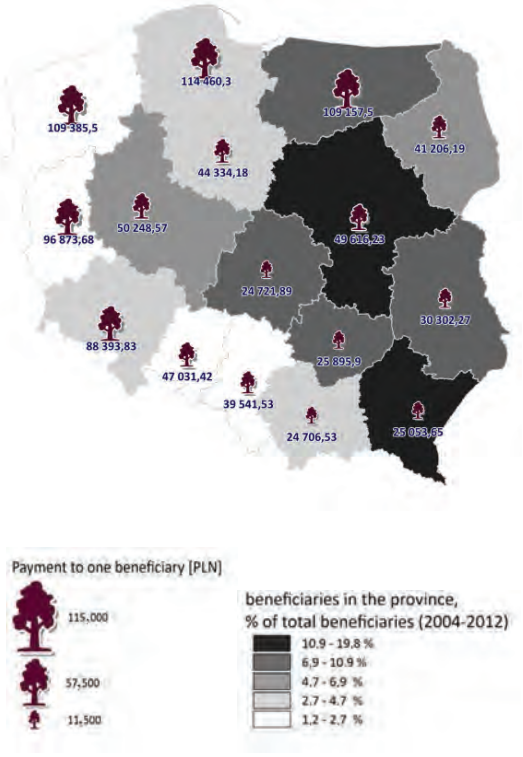

Figure 3. Activities of beneficiaries conducting afforestation in counties and number of applications (commitments contracted within the framework of the RDP 2004-2006 and RDP 2007 – 2013 as of 31 December 2012.

land other than agricultural under the RDP 2007 – 2013, the total of 15,500 commitments to beneficiaries were contracted in Poland. Until 31 December 2012, payments to the total amount of 650 million PLN had been disbursed.

Based on the disbursements as at the end of 2012 to the beneficiaries conducting afforestation on agricultural lands and lands other than agricultural (commitments contracted within the framework of the RDP 2004 – 2006 and RDP 2007 – 2013), it can be concluded that farmers from the central and eastern part of the country, mainly Mazowieckie and Podkarpackie voivodships showed the highest levels of activity (Fig. 2). However, the highest average disbursements per single application occurred in northern and western Poland (voivodships: Pomorskie, Zachodniopomorskie, Warmińsko-Mazurskie, Lubuskie and Dolnośląskie) (Fig. 2.). As concerns the spatial distribution of beneficiaries' activity given the number of applications lodged with county offices of the ARMA (counties), certain disproportions are clearly visible (Fig. 3). In Mazowieckie voivodship farmers from 6 counties only showed high interest in afforestation within the framework of the RDP. The City of Warsaw County where the largest number of applications for afforestation (or where afforestation was continued based on commitments contracted within the framework of the RDP 2004 – 2006) deserves a particular attention. This results from the fact that the farmers lodge applications with the county office of ARMA territorially competent for the registered address of the farm and not with the actual location of the agricultural land.

Figure 4 covers funds for afforestation within the framework of the RDP 2007 – 2013 considering the programming period during which the commitment to the beneficiary was made (2004 – 2006 or 2007 – 2012). Afforestation projects implemented during the first financial perspective (2004 – 2006) were passed for financing from the RDP 2007 – 2013 budget (care bonus and afforestation bonus). The afforestation rate increase was defined for the years 2004 – 2012, and it covers the afforestation projects implemented by both the private sector and the State Treasury.

Based on Fig. 4, it can be concluded that the activity of agricultural farms measured by the number of applications lodged is diversified. It decreases from the south-east towards the west of the country. Mazowieckie voivodship generated the most favourable results. The highest number of applications was lodged there, and a significant amount of disbursements (21% of the budget) was made there. A significant increase in the afforestation rate was also recorded in the region. Warmińsko-Mazurskie voivodship was the second in the volume of disbursements for afforestation. It is characterised by better soils (particularly in the northern part) and a high percentage of large farms (exceeding 20 ha). Hence, the average disbursement per a single

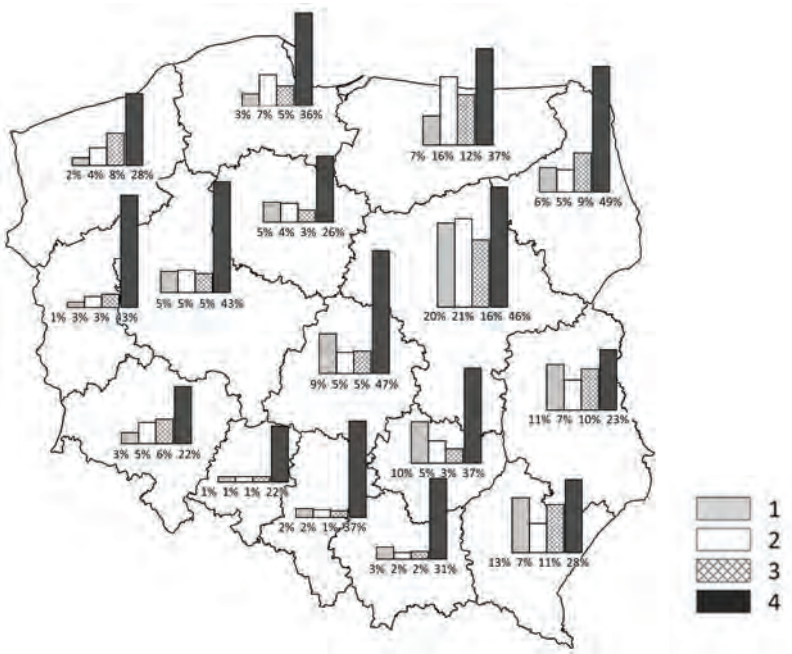

Figure 4. Afforestation financed within the framework of the RDP 2007 – 2013:
1- number of applications (%), 2 – payments disbursed (%), 3 – afforestation rate increase (%),
4 – area of class V, VI and VIz soils (%).

application is among the highest disbursements nationwide (109,500 PLN).

Conclusions

There are many voivodships in the country with extensive recommendations for afforestation. Based on the research, we can draw the following conclusions:

1. Significant increase in the share of private ownership in forest structure confirms the large impact of the RDP on increasing afforestation rate in the country.
2. The farmers are unwilling to conduct afforestation even on poor soils because afforestation means permanent exclusion of land from agricultural production. Podlaskie voivodship in north-east Poland is an example. It is characterised by the worst suitability of land for the agricultural production, but it is seen as a typically agricultural region (dairy production).
3. Planning conditions also represent a significant constraint to afforestation of agricultural land. Afforestation can be carried out on condition that it is not contrary to the findings of the study of conditions and directions of spatial development of the commune, or if the local spatial development plan in which areas for afforestation are considered, has been enacted.
4. During the implementation of the RDP 2007 – 2012, during the period of 2007 – 2013, the total of 650 million PLN was disbursed to Polish farmers. The RDP funds absorption level is also confirmed by the average payment per 1 application. The national average disbursement was at the level of 42,000 PLN, but the diversification of disbursements was large. The lowest average disbursements were recorded in the southern voivodships (ca. 25,000 PLN) but the highest in the northern part of the country (under 100 thousand PLN).
5. In Poland, since 2004, the value of agricultural land has significantly increased. This is the reason why farmers are reluctant to afforestation projects. Afforestation premium does not compensate the farmer enough to abandon the crop field. In this situation, farmers expect much higher rates in the RDP 2014 – 2020.
6. Given the high percentage of poor soils in the structure of agricultural land and availability of funding for afforestation to Polish farmers within the framework of the European Union funds we should hope that the private sector can play a significant role in increasing the afforestation ratio of the country.
7. Rational implementation of new afforestation projects may also contribute to better organisation of the agricultural-forest border with the benefit to landscape value, functioning of forests and agriculture.
8. The determination factor in the afforestation of agricultural land is the availability on the market of agricultural property and its market value. Natural conditions and soil quality is of secondary importance. As confirmed by studies from the point of view of each beneficiary, the most important is the cost-effectiveness of afforestation.

References

1. Biczkowski M., Głaz M. (2012) Zalesienia gruntów rolnych, jako element planowania i kształtowania rozwoju przestrzeni wiejskiej. In: Kurowska K., Gwiaździńska-Goraj M. (red.) Planowanie rozwoju przestrzeni wiejskiej (Planning Spatial Development in Rural Areas). *Studia Obszarów Wiejskich*, t. 29, IGiPZ PAN Warszawa, s. 209 – 230. (in Polish).
2. Biczkowski M., Rudnicki R. (2013) Spatial Differentiation and the Effects of the "Afforestation of Agricultural Land" in Poland, Rural Development 2013.*The sixth international scientific conference*. Aleksandras Stulginskis University, Kaunas, Volume 6, Book 1, pp. 499 – 506.
3. Bórawski P. (2010) PROW jako źródło środków finansowych umożliwiających rozwój obszarów wiejskich (RDP as a source of funds enabling rural areas development). 85, s. 35 – 42. (in Polish).
4. Bułkowska M., Chmurzyńska K. (2011) State Policy towards Rural Areas – Targets and Target Implementation. Rural Development 2011. *The fifth international scientific conference*. Aleksandras Stulginskis University, Kaunas, Volume 5, Book 1, pp. 84 – 91.
5. Concise Statistical Yearbook of Poland (2012) Central Statistical Office, Warsaw, pp. 342; 630.
6. Droździel L. (eds.) (2007) ARiMR – trzy lata po akcesji (ARMA – three years after accession). *Agency for Restructuring and Modernisation of Agriculture*, Warsaw, s. 61. (in Polish).
7. Duesberg S., O'Connor D., Ní Dhubháin Á. (2013) To plant or not to plant – Irish farmers' goals and values with regard to afforestation. *Land Use Policy,* 32, pp. 155 – 164.
8. Forestry (2013) Central Statistical Office, Warsaw, pp. 271 – 272.
9. Jarský V., Pulkrab K. (2013) Analysis of EU support for managed succession of agricultural land in the Czech Republic. *Land Use Policy,* 35, pp. 237 – 246.

10. Kołodziejczak A., Rudnicki R. (2012) Instrumenty Wspólnej Polityki Rolnej ukierunkowane na poprawę środowiska przyrodniczego a planowanie przestrzenne rolnictwa (Environmentally-oriented Common Agricultural Policy instruments and physical planning in agriculture) *Acta Scientiarum Polonorum Administratio Locorum*, T. 11 nr 2, s. 117 – 133. (in Polish).
11. KPZL (2003) Krajowy Program Zwiększania Lesistości, z dnia 23 czerwca 1995 r. (National Programme for Increasing the Afforestation Rate, of 23 June 1995). Ministry of Environment, Warsaw, s. 2 – 53. (in Polish).
12. Louwagie G., Gay S.H., Sammeth F., Ratinger T. (2011) The potential of European Union policies to address soil degradation in agriculture. *Land Degradadion & Development,* 25, pp. 5 – 17.
13. Płotkowski L. (2008) Zalesienia gruntów rolnych w programie Rozwoju Obszarów Wiejskich na lata 2007 – 2013 (Afforestation of agricultural land in the Rural Development Programme 2007 – 2013). *Zeszyty Naukowe Szkoły Głównej Gospodarstwa Wiejskiego*, s. 35 – 42. (in Polish).
14. Polna M. (2007) Zróżnicowanie przestrzenne a uwarunkowania przyrodnicze zalesień gruntów rolnych w Polsce, (Spatial diversification and nature conditions of afforestation of agricultural land in Poland (in:) Grykień S., Hasiński W. (eds.) Przyrodnicze uwarunkowania rozwoju obszarów wiejskich (Environmental Conditioning of Rural areas Development) *Studia Obszarów Wiejskich*, t. 12, IGiPZ PAN Warszawa, s. 129 – 139. (in Polish).
15. Polna M., Szczepański Ł. (2010) Skala i zróżnicowanie przestrzenne absorpcji funduszy UE na przykładzie działania „Zalesianie gruntów rolnych" w województwie wielkopolskim w latach 2004 – 2006 (Scale of and spatial differences in the absorption of EU funds: The measure „Afforestation of agricultural land"). (in:) R. Rudnicki (eds.), Fundusze Unii Europejskiej jako czynnik modernizacji rolnictwa polskiego (European Union funds as a factor of modernisation of Polish agriculture), *Studia i Prace z Geografii i Geologii*, 7, Bogucki Wydawnictwo Naukowe, Poznań, s. 127 – 140. (in Polish).
16. Polna M. (2011) Indywidualne gospodarstwa rolne jako beneficjenci działania 5. PROW „Zalesienia gruntów rolnych" w województwie wielkopolskim (Individually owned agricultural holdings as beneficiaries of RDP measure 5, „Afforestation of agricultural land" in Wielkopolskie Voivodship). *Journal of Agribusiness and Rural Development,* 3(21), s. 81 – 91. (in Polish).
17. Rural Development Plan 2004 – 2006 (2004) Ministry of Agriculture and Rural Development, Warsaw, pp. 127 – 133.
18. Rural Development Programme 2007 – 2013 (2007) Ministry of Agriculture and Rural Development, Warsaw, pp. 284 – 295.
19. Rudnicki R. (2010) Zróżnicowanie przestrzenne wykorzystania funduszy Unii Europejskiej przez gospodarstwa rolne w Polsce w latach 2004 – 2006 (Spatial diversification of the European Union funds use by agricultural farms in Poland during the years 2004 – 2006). *Seria Studia i Prace z Geografii i Geologii,* nr 17, Bogucki Wydawnictwo Naukowe, Poznań, Poland, s. 184 – 206. (in Polish).
20. Rudnicki R. (2013) Zróżnicowanie przestrzenne absorpcji funduszy Unii Europejskiej w rolnictwie polskim jako problem badawczy i aplikacyjny (Spatial differences in the absorption of European Union funds by Polish agriculture as a research and application problem), *Acta Universitatis Lodzienis, Folia Geographica Socio-Oeconomica*, 13, s. 71 – 92. (in Polish).
21. Skłodowski P., Bielska A. (2009) Właściwości i urodzajność gleb polski – podstawą kształtowania relacji rolno-środowiskowych (Properties and fertility of soils in Poland – a basis for the formation of agro-environmental relations). *Woda-środowisko-obszary wiejskie*, t. 9 z. 4 (28), s. 203 – 214. (in Polish).
22. Statistical Yearbook of the Republic of Poland (2012) Central Statistical Office, Warsaw, p. 36.
23. Szujecki A. (2003) Zalesienia gruntów porolnych jako problem polityczny (Afforestation of post-agricultural lands as a political issue). In: *Zalesienia w Europie – doświadczenia i zamierzenia (Afforestation in Europe – experiences and plans).* Instytut Badawczy Leśnictwa, Warsaw, s. 116 – 125. (in Polish).
24. Upite I., Pilvere I. (2011) The EU Common Agricultural Policy Implementation in Latvia, Rural Development 2011.*The fifth international scientific conference*. Aleksandras Stulginskis University, Kaunas, Volume 5, Book 1, pp. 261 – 267.

CHANGES IN THE WOODY VEGETATION OF MACRO CLEARANCES IN VIŠTYTGIRIS BOTANICAL-ZOOLOGICAL RESERVE

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Abstract
An important factor in the development of forest ecosystem is the ability to regenerate. Natural intensity of self-thinning of a forest depends on the tree species and environmental conditions. Due to abiotic and biotic factors in a continuous forest tract, there appears a clearing, which, depending on the size, forms new growth conditions. Over time, the resulting new space is occupied by herbaceous and woody vegetation. Most often regeneration of a new forest depends on the size of the plot.
The study was conducted in 2013 during the growing season in a typical broadleaf forest stand. During the study woody vegetation and projection coverage of herbaceous vegetation was registered in large clearings. Light conditions in the plots and under tree canopies, as well as soil parameters were ascertained. Based on the collected data, the view of the structure of woody vegetation, projection coverage of herbaceous vegetation, light conditions, temperature, soil moisture content and pH changes were obtained. In order to clarify the influence of microclimatic conditions on natural forest regeneration, the data on light and soil characteristics were analyzed.
The aim of the study - was to determine the changes of woody and herbaceous vegetation in spruce stand clearings and to assess the impact of microclimate.
During the study it was found out that in large plots dominated species demanding higher amount of light, while herbaceous vegetation was attributed to the third, fourth groups of aggressiveness. Naturally regenerated seedlings condition was mostly influenced by light conditions and soil moisture content.
Key words: species composition, natural regeneration, forest plots, environmental conditions.

Introduction

The intensity of self-thinning in the forest depends on stand species composition, on the abundance and location of fruiting trees in the surroundings, soil type, relief and other conditions of the regenerating site (Ozolinčius, 2008; Riepšas, 2008). To ensure successful self-regeneration of a forest, it is important to identify favorable and unfavorable factors that determine the success of regeneration and the state of stand. For natural forest regeneration crucial is the distance to the seed source and soil potential to sprout seeds and maintain viable seedlings. Forest reproductive characteristics depend not only on tree species and age, but also on local conditions: light, heat, soil moisture, herbaceous vegetation and other irregularities (Ozolinčius, 2008; Suchockas, 2004).

Naturally regenerated seedlings are sensitive to sudden changes in the environment (light, temperature and humidity). Unable to withstand competition, most of them die. Taller (5-10 years) seedlings, which earlier could stand some shading, now require better light conditions. Later, in the absence of sufficient light, the saplings grow slower and become underbrush or die (Ministry of Environment, 2010). Solar radiation is the most important factor for all green plants, as well as for the existence of forest ecosystems. Light regime in forest plots depends on their structure and layout. Light demand of individual species of trees and shrubs depends on the age of the plant, vitality, growth conditions, stand species composition, structure, stocking level and other factors (Karazija, 2008; Ozolinčius, 2008; Barko and Adams, 1986). Soil moisture content is a key factor limiting seed germination and the development of seedlings. Average humidity in the forest is by about 9% higher than in the open field; thus, the new generation of forest has better growth conditions under the canopies of stands (Suchockas, 2004).

Forest is not an entire body; it is characterized by storeys, mosaic appearance and fragmentation. Forest structure is determined by the structure of plant communities; namely, spatial arrangement of its elements, composition of plant species, quantitative ratio of species, growth conditions. Clearings are a part of forest structure. According to Forest Management Guide of the State Forest Service under the Ministry of Environment, a clearing (a forest plot) is defined as an area of not less than 0.1 ha, which had been overgrown with a forest, but due to natural, anthropogenic or other factors was deprived of it for more than 10 years.

In an entire forest tract the formation of clearings is strongly influenced by abiotic and biotic environmental factors. Clearings, depending on the size, form new growth conditions. Over time, the communities of herbaceous and woody vegetation occupy a new space. Dead individuals or groups of several trees comprise small forest areas, called micro plots, while groups of dead trees comprise larger areas, called macro plots. Regeneration of the new forest mostly depends on the size of the clearing. In plots of different size dominate different light conditions, moisture content and the

amount of nutrients. Under the influence of prevailing conditions, plant species, which are adapted to certain tolerance for light, soil, moisture content regenerate in the plots (Sturrock, 2012; Sturtevant and Gustafson, 2004; McCarthy, 2001; Gray and Spies, 1996; White and Pickett, 1985).

Materials and Methods

The object of research – was large observation plots of broadleaved forests in Vištytgiris botanical-zoological reserve.

Vištytgiris botanical - zoological reserve is in the territory of Vilkaviskis district municipality. The reserve is located in the State Regional Park of Vištytis - in Vištytgiris forest, and it was established in 1992 in order to preserve typical broad-leaved forest communities with a rich and diverse flora and fauna. The reserve covers 657 hectares and the central part of Vištytgiris forest. According to the Lithuanian climatic classification, the object of study is in Sūduva subarea of Lithuanian Southeast Highland climatic region. The average annual precipitation is about 550-650 mm. Average annual air temperature - 7.5 °C, total solar radiation - ≥ 3500 MJ m^2, while absorbed solar radiation - 2800 MJ m^2 per year.

Dominant species in Vištytgiris botanical-zoological reserve - are as follow: *Picea abies* L., *Populus tremula* L., *Quercus robur* L., *Tilia cordata* Mill., *Acer platanoides* L., *Betula pendula* Roth., *Carpinus betulus* L. In damp and wet locations: - there is *Alnus glutinosa* L. Based on botanical research data of 1998, spontaneous vascular flora of the reserve comprised 439 plant species: 17 vascular sporous species, 2 gymnosperms and 420 angiosperms. Trees comprised 21 species, mosses - 111, herbaceous plants - 418, adventitious plants - 6 species (Natural and Environmental Education Research Station, 1998). The reserve is on the list of natural habitats of European significance corresponding to the selection criteria for the protection of Natura 2000 sites.

For the assessment of woody and herbaceous vegetation, five large experimental plots (~ 150 m^2) were identified during the growing season (June) in 2013. To determine woody vegetation, a strip transect with a width of 2 m was used. The density of woody vegetation was measured up to 50 cm and above 50 cm. In subsequent calculations the number of woody plants was converted into trees ha^{-1}. For the assessment of projection coverage of grassy vegetation, in each large plot, 3 square-shaped plots of 1 m^2 (1 x 1 m size) were randomly selected. Projection coverage was determined visually. It was determined what surface (in percentage points) is covered by each species of herbaceous plants.

Soil moisture content, pH and temperature were determined using a portable device 'WET'. These indicators were measured on soil surface and at a depth of 5 cm. On each site, measurements were conducted in the centre, and near the edge of the plot with three replications. Lighting was measured in the centre of each plot, at the edge and nearby the plot using the device 'Hemi View Canopy System'. To analyze light intensity, hemispherical photographs and a computer program Hemi View were used. Direct, diffuse and total radiation was analyzed to determine light intensity in the plots.

In order to ascertain the influence of microclimatic conditions on the growth and development of vegetation, soil temperature, moisture, pH and light intensity in the plots were analyzed.

Results and Discussion

Different species are found in forest plots of varying size. In large forest plots species requiring more light and higher temperature are found. According to H.Ellenberg (1991), *Populus tremula* L., *Betula pendula* Roth., *Quercus robur* L. are attributed to semi - light-demanding species. On average, *Populus tremula* L. was dominant tree species in large plots, and comprised five parts in the species composition (Table 1).

The lowest diversity of species composition was in the fifth plot (3 species), while the highest - in the second and fourth plots (5 species). Dominant species in large plots were *Populus tremula* L. (10 – 80%), *Picea abies* L. (10 – 60%), other species accounted for a small portion (10 – 20%) of the species composition. The maximum amount of *Populus tremula* L. natural regeneration was in the fifth plot (8 parts), while that of *Picea abies* L. – in the second plot (6 parts). In the first plot there was no woody vegetation, it was dominated only by grassy vegetation.

In calculations the number of woody plants was converted into trees ha^{-1}, using the proportions as in forest inventory. Having recalculated the amount of natural regeneration to trees ha^{-1}, it was found that stand density is higher than the norm. Only the density of natural regeneration of *Tilia cordata* L. and *Quercus robur* L. in the fourth plot and *Tilia cordata* L. in the second plot was lower than the norm.

The highest soil temperature in the center of the plot was in the fourth and fifth plots, respectively by 2. 2 °C and 1.3 °C higher than the mean (24.8 ± 0.73 °C) one, while in the third plot it was by 2.1 °C lower than the mean (Figure 1).

Mean soil temperature on the edge of plots was 22.6 ± 0.59 °C, i.e by 1.5 °C higher than the lowest (the third plot – 21.1 °C), and by 1.9 °C lower than the highest (the fourth plot – 24.5 °C) soil temperature. In the fourth plot soil temperature in the forest was the highest (24.3 °C), while on other sites it was close to the mean (21.8 ± 0.83 °C). Minimum soil temperature difference between the center point, the edge and the forest was ascertained in the third plot,

Table 1

Stand species composition and density in large plots

Plot No.	Stand species composition	Up to 50 cm		Above 50 cm	
		Stand density thou. pcs/ha (according to standard)	Stand density thou. pcs/ha (in site)	Stand density thou. pcs/ha (according to standard)	Stand density thou. pcs/ha (in site)
1	-	-	-	-	-
2	6E	2.16	9.75	-	-
	1B	0.36	2.00	-	-
	1D	0.24	1.50	-	-
	1Ą	0.36	0.50	-	-
	1L	0.36	0.25	-	-
3	5D	0.48	14.75	0.60	20.75
	2E	0.36	8.75	0.30	1.75
	2B	0.36	4.25	0.30	8.50
	1Ą	0.36	0.50	-	-
4	5D	0.72	24.25	0.40	15.50
	2E	0.36	8.25	0.30	2.25
	1B	0.36	3.50	-	-
	1L	0.36	0.25	-	-
	1Ą	0.36	0.25	-	-
5	8D	0.72	1.75	1.00	2.75
	1L	-	-	0.30	0.50
	1E	0.36	0.75	-	-

* E –*Picea abies* L.; B –*Betula pendula* Roth., D –*Populus tremula* L., Ą – *Quercus robur* L., L – *Tilia cordata* L., K – *Acer platanoides* L.

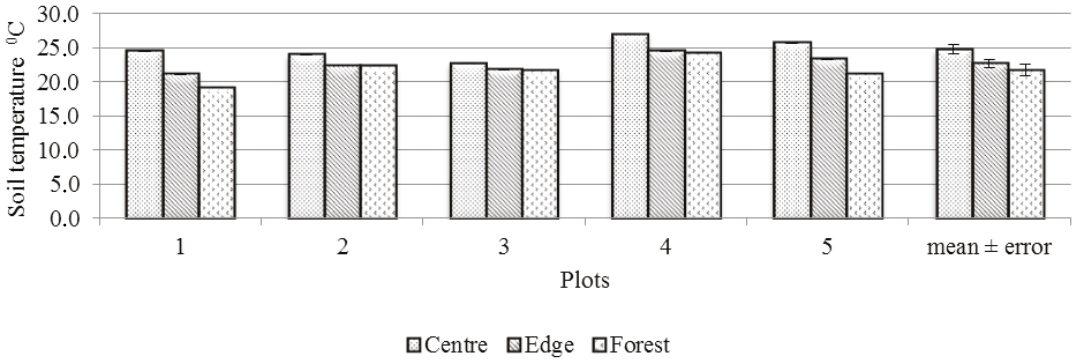

Figure 1. Soil temperature in the centre, at the edge and in the forest of large plots.

while maximum - in the first, comprising respectively 1.0 °C and 5.3 °C.

A statistically significant relationship was found between soil temperature and the amount of *Tilia cordata* Mill. natural regeneration ($r = -0.82$, $p = 0.03$). Among other species no statistically significant relationship ($p>0.05$) was determined.

Soil moisture content variation between the center point, the edge and the forest was the lowest in the fourth plot, while the highest - in the third (Figure 2). The average soil moisture content in the center of plots was 4.88 ± 1.79%, by 6.5% lower than in the second plot (11.4%). Moisture content determined in the center of the first and third plots was close to the average, respectively 5.0% and 4.9%, while in the fourth and fifth plots a very low soil moisture content was determined, 1.4 and 1.7% respectively. The highest soil moisture content was at the edge of the second (15.6%) and the third (17.5%) plots, by 40 – 60% higher than the average (11.08 ± 2.47%). The lowest soil moisture content was found at the edge of the first (by 34 % lower than the average) and

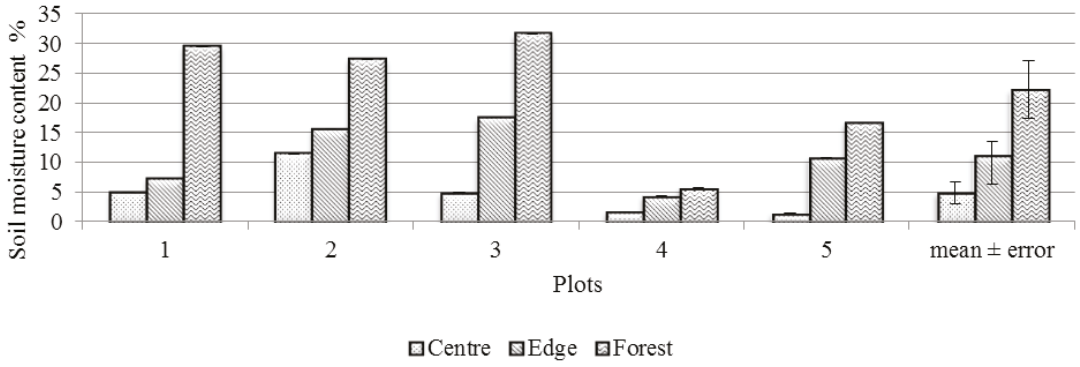

Figure 2. Soil moisture content in the centre, edge of large plots and in the forest.

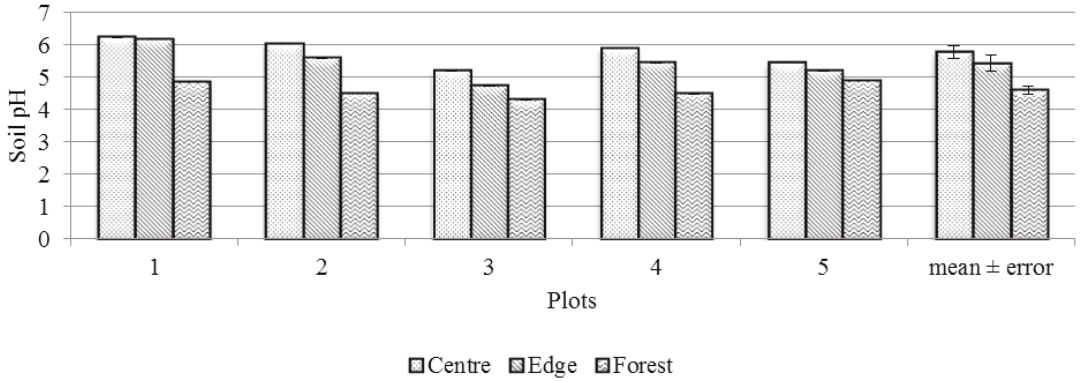

Figure 3. Soil pH in the centre, the edge of large plots and in the forest.

the fourth (by 61% lower than the average) plots. Soil moisture content in the forest of the first plot was by 33 %, that of the second plot by 24%, that of the third - by 43 % higher than the average (22.18 ± 4.85%), while in the fourth plot – by 74% lower.

A statistically significant relationship was found between soil moisture and the amount of natural regeneration of *Picea abies* L. (r = 0.96, p = 0.04), *Populus tremula* L. (r = -0.91, p = 0.05). No statistically significant relationship (p>0.05) was ascertained among other tree species.

The highest soil pH was measured in the centre of plots, the lowest - in the forest (Figure 3). The highest soil pH was in the centre of the first plot (pH = 6.24), while the lowest in the forest of the third (pH = 4.30) plot. A slightly acidic soil (pH = 6.0 to 6.9) was found in the centre and the edge of the first plot (respectively, pH = 6.24 and 6.19), and in the centre of the second plot (pH = 3.05). A slightly acidic soil was ascertained at the edge of the second plot (pH = 5.60), in the centre of the third (pH = 5.20), and in the centre and the edge of the fourth and the fifth plots (pH from 5.20 to 5.90). At the edge of the fourth plot soil pH (pH = 5.45) was close to the average (pH= 5.43 ± 0.24). Averagely acidic soil was found in the forest of all plots (pH from 4.30 to 4.90) and at the edge of the third plot (pH = 4.73).

A statistically significant relationship was ascertained between soil pH and the amount of regeneration of *Betula pendula* Roth. (r = -0.98, p = 0.05). Among the other species no statistically significant relationship (p>0.05) was ascertained.

Light conditions in the centre of forest plots, at the edge and in the forest are shown in Table 2. The maximum diffuse radiation was recorded in the center (395 MJ, m^2) and at the edge (298 MJ, m^2) of the first plot. Diffuse radiation in the forest of the first and second plots was close to the average (206 ± 3.7 MJ, m^2), respectively, 205 MJ, m^2 and 204 MJ, m^2. Average diffuse radiation in the center of the plot was 320 ± 24.0 MJ, m^2, direct radiation - 708 ± 61.0 MJ, m^2 and the total radiation - 1027 ± 59.0 MJ, m^2, while total radiation in the centre of the plot was 31.16%. The biggest difference (179 MJ, m^2) between the average direct radiation in the center was found in the third plot. Maximum total radiation (1178 MJ, m^2) in the centre was in the third plot, while the lowest (862 MJ, m^2) - in the fifth plot.

Under the impact of forest regeneration, a live soil cover is divided into groups of aggressiveness

Table 2

Results of lighting experiment in the center, at the edge of large plots and in the forest

Plot No.	Light measurement location	Direct radiation	Dispersed radiation	Total radiation
1	Centre	395	563	959
	Edge	298	421	719
	Forest	205	620	825
2	Centre	316	677	993
	Edge	261	458	719
	Forest	204	864	1068
3	Centre	291	887	1178
	Edge	240	519	759
	Forest	215	742	957
4	Centre	341	805	1146
	Edge	230	536	766
	Forest	194	636	830
5	Centre	254	608	862
	Edge	182	623	805
	Forest	212	609	821
mean ± error	Centre	320 ± 24.0	708 ± 61.0	1027 ± 59.0
	Edge	242 ± 19.1	511 ± 34.8	754 ± 16.2
	Forest	206 ± 3.7	694 ± 49.0	900 ± 49.0

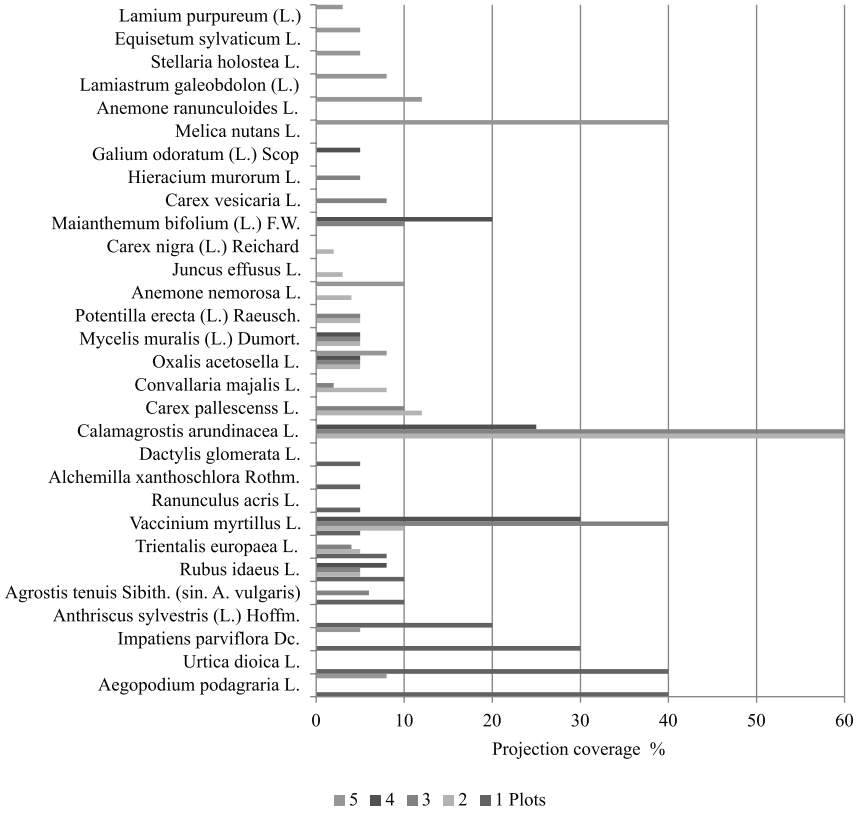

Figure 5. Projection coverage of grassy vegetation in large plots.

(Karazija, 2008). Grass cover of large plots is attributed to the third group of aggressiveness, with the exception of the first plot (entire cover of tall grasses shading the undergrowth) - the fourth group of aggression.

Projection coverage of the species composition of grassy vegetation cover ranges from 3% to 60% (Figure 5). Most species of herbaceous vegetation were found in the third and second plots, 13 and 12 species respectively, while the least (7 species) – in the fourth plot. The highest (60%) projection coverage was by *Calamagrostis arundinacea* L. (in the second and third plots), 40% projection coverage by *Melica nutans* L. (the fifth plot), *Vaccinium myrtillus* L. (the third plot), *Aegopodium podagraria* L. and *Urtica dioica* L. (the first plot), while projection coverage of other herbaceous plants ranged from 10 to 30%. The minimum projection coverage was by *Carex nigra* (L.) Reichard (the second plot), *Convallaria majalis* L. (the third plot) - 2% and *Juncus effusus* L. (the second plot), *Lamium purpureum* (L.) (the fifth plot) – 3%.

Conclusions

1. In large forest plots, semi light-demanding tree species dominated, and the largest portion comprised *Populus tremula* L. - five parts within species composition, while shade-preferring species *Picea abies* L. - three parts.
2. Soil temperature in the center of the plots was by 3.0 °C higher than the temperature in the forest, and this contributed to higher amount of diffuse radiation entering the centre of plots (diffuse radiation in the centre of plots comprised 320 ± 24.0 MJ, m^2, while in the forest - 206 ± 3.7 MJ, m^2).
3. Natural forest regeneration was mostly influenced by soil moisture content. In the center of plots soil moisture content was by 8.72% lower than in the forest. In the centre of large plots, slightly acidic soil (pH = 5.77), prevailed, while the forest soil was averagely acidic (pH = 4.61).

References

1. Barko J.W., Adams M.S., Clesceri N.L. (1986) Environmental Factors and Their Consideration in the Management of Submersed Aquatic Vegetation: A review. *J. Aquat. Plant. Manage.* 24, pp. 1 – 10.
2. Gray A.N., Spies T.A. (1996) Gap size, within-gap position and canopy structure effects on conifer seedling establishment. *Journal of Ecology.* 84, pp. 635 – 645.
3. Karazija S. (2008) *Forest ecology*, Encyclopedia, Vilnius, pp. 54 – 153.
4. Ministry of Environment (2010) Forest owner primer. *Ministry of Environment of the Republic of Lithuania,* 88. p.
5. McCarthy J. (2001) Gap dynamics of forest trees: A review with particular attention to boreal forests. *Forest Sciences Department, Faculty of Forestry, University of British Columbia, Vancouver, Canada,* B.C. VGT 1Z4. *Environmental Review.* 9, pp. 1 – 59.
6. Ozolinčius R. (2008) *Forest ecology and silviculture: Forest vegetation methods*, Kaunas, 235 p.
7. Riepšas E. (2008) *Forest ecology,* Textbook (compiler Karazija S. (2008)), Vilnius, 296 p.
8. Sturrock N.R. (2012) Climate change and forest diseases: using today's knowledge to address future challenges. *Forest Systems 2012,* 21(2), pp. 329 – 336; pp. 330 – 331.
9. Sturtevant B.R., Gustafson E.J., Li W., He H.S. (2004) Modeling biological disturbances in LANDIS: a module description and demonstration using spruce budworm. *Science Direct, Ecological Modelling,* 180(1), pp. 153 – 174.
10. Suchockas V. (2004) Natural regeneration of birch (*Betula pendula*) agricultural lands. *Lithuanian Forest Research Institute, Agricultural Sciences*, 2004. No. 2, pp. 52 – 59.
11. White P.S., Pickett S.T.A. (1985) Natural disturbance and patch dynamics: an introduction. *In* The ecology of natural disturbance and patch dynamics. *Academic Press, San Diego, Calif.,* pp. 3 – 13.

THE INFLUENCE OF FOREST DISTRIBUTION IN THE LANDSCAPE OF LITHUANIA ON THE AMOUNT OF PRECIPITATION

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Abstract
The influence of forest distribution in the landscape on precipitation in middle latitudes is poorly researched. Moreover, results of such studies are controversial. Nevertheless, most researchers agree with findings, that influence of landscape roughness formed by forests on the amount of precipitation is significant. This study aimed to extend knowledge of the interface between forest distribution and the amount of precipitation during particular periods. Database of the amount of precipitation from 31 Lithuanian meteorological stations during the period of 2002-2010 was used in this study. Findings defined statistically significant correlations in the amount of precipitation increase due to shorter Euclidean distance to the nearest forest edge in the particular landscape ($r = -0.421 – -0.359$), $p < 0.05$), also shorter distance of the meteorological stations to the nearest forests ($r = -0.380$, $p < 0.05$) and higher density of the forests, treated as a perimeter per area ratio (PAR) ($r = 0.359 – 0.551$, $p < 0.05$).
Key words: the amount of precipitation, landscape roughness, forest distribution index, perimeter per area ratio (PAR).

Introduction

Numerous scientific publications focus on forest influence on climate change, concerning large-scale afforestation in tropical rain forest region, started in the 20th century (Avissar and Werth, 2005; Findell and Knutson, 2006; Hasler et al., 2009; Lee and Berbery, 2012; McGuffie et al., 1995; Medvigy et al., 2011; Negri et al., 2004; Nobre et al., 1991; Shukla et al., 1990; Voldoire and Royer 2005; Wang et al., 2000, 2009; Werth and Avissar, 2002; Zhang et al., 1996a, b). It has been recognized that dramatic land surface changes in this region may affect regional climate variations and even global changes due to Rossby waves. Although the influence of tropical forests on local and regional precipitation is certainly considerable, the impact of forests in middle latitudes on local climate change is still a question of discussions.

The very first studies (Brown, 1877; Hazen, 1897; Kittredge, 1948; Rakhmanov, 1963; Zon, 1927), dealing with forest influence on precipitation, quite well defined the impact of forests on precipitation. J. C. Brown (1877) pointed out that warm air masses of atmosphere, moving over the forests, cools down and condenses to precipitation, when the air temperature falls below the dew point. V. V. Rakhmanov (1963) indicated that a forest cover, forming a landscape roughness, can slow down the air masses and generate turbulent wind forces to the edge of forests thus enabling precipitation. More recent studies approved these statements (Anthes, 1984; Avissar and Liu, 1996; Knox et al., 2011; Maat et al., 2012; Wang et al., 2009).

Just a few studies analyzing interface between forests and precipitation were implemented in Lithuania (Pauliukevičius and Kenstavičius, 1995; Raguotis, 1977). Moreover, some researchers even got no significant results between the amount of precipitation and forest cover of Lithuania Republic (Raguotis, 1977), though findings of our earlier study revealed the direct effect of percentage of land covering with forests on the amount of precipitation (Ruseckas and Tiškutė-Memgaudienė, 2013).

Whereas fundamental knowledge in this field is ambiguous and obscure, following research, studying influence of landscape roughness, formed by forest distribution, on the amount of precipitation, was performed.

The aim of this study is to compare impact of different forest distribution parameters such as forest perimeter per area ratio (PAR), mean distance of meteorological stations to the nearest forest edge and mean Euclidean distance to the nearest forest in a particular area (forest distribution index) on the amount of precipitation. The findings of the presented study may help us to understand better the peculiarities of redistribution of the amount of precipitation and effect of afforested lands on formation of the amount of precipitation. Due to the fact that precipitation resulted both in positive and negative changes in forest condition and productivity (Augustaitis et al., 2009; 2010; Masaitis et al., 2013) new findings should help in preparation of the forest treatments which would allow to ensure the sustainable development of forest ecosystem in future (Augustaitis et al., 2014).

Materials and Methods

The study was based on 2002-2010 precipitation database available from 31 Lithuanian main meteorological or other (automatic meteorological, agrometeorological, hydrological) stations, continuously collecting precipitation data. Geodatabase of forest cover in Lithuania Republic was obtained from Lithuanian forest cadastre (2011).

Such factors as forest perimeter per area ratio (PAR), mean distance of meteorological stations to the nearest forest edge and mean Euclidean distance to the nearest forest in a particular area treated as forest distribution index were used in this study, studying the impact of landscape roughness on the amount of precipitation.

Circular 5 km, 10 km, 15 km, 20 km radius buffers, in tables referred to as 'r_1 = 5 km', 'r_2 = 10 km', 'r_3 = 15 km', 'r_4 = 20 km' respectively, around each meteorological station, were generated (X and Y coordinates of meteorological stations were used as a center of circles). A total of 124 buffers was obtained in each computed forest perimeter. In order to calculate PAR indexes in every studied area, perimeters of forest polygons and circular buffer area values were used.

Buffers of 15 km radius were used for data collection of mean distance of meteorological stations to the nearest forest edge, splitting them to eight *Pie* segments in each buffer, orientated to cardinal and ordinal direction (north (N), east (E), south (S), north (N), northeast (NE), southeast (SE), southwest (SW), northwest (NW)). The nearest distance to the forests was computed in each segment, searching the mean value subsequently.

Forest distribution in the landscape was defined by the grid of Euclidean distance of cells to the nearest forests, covering an entire territory of Lithuania. This parameter characterizes forest distribution in the landscape of Lithuania. Mean Euclidean distance to forests was calculated in each considered buffer, using zonal statistics. This parameter is referred to as forest distribution index.

Pearson correlation analysis was applied for assessing the relationships between landscape roughness formed by forest distribution and the amount of precipitation. Statistical analysis was performed employing the techniques of 'Statistica 8.0' software.

Results and Discussions

Forests in Lithuanian landscape are distributed differently – patchy forest landscapes shift towards forest tracts, or contrarily, to urbanized or rural countryside with small isolated forest areas. Such statement was made investigating the overall graphic results of forest distribution (Figure 1) and statistical data of Euclidean distances to forests in particular neighborhood areas of meteorological stations (Table 1).

The mean Euclidean distance to forests, referred to as forest distribution index, in particular areas reached 315.6±23.0 m (SD = 215.85, N = 186) and ranged from 18.8 m to 1464.1 m. Forest distribution results should be explained as follows: the larger is mean Euclidean distance to the forest in landscape, the higher is forest fragmentation and the lower is concentration in forest tracts (raster distance to the forest in forested area is zero (0.0 m)).

Forest distribution in Lithuanian landscape tends to influence the distribution of precipitation in the country – such findings were revealed from our research.

Significant reverse relationships ($r = -0.421$ – -0.359, $p < 0.05$) between the amount of precipitation and forest distribution index (Table 1) was found

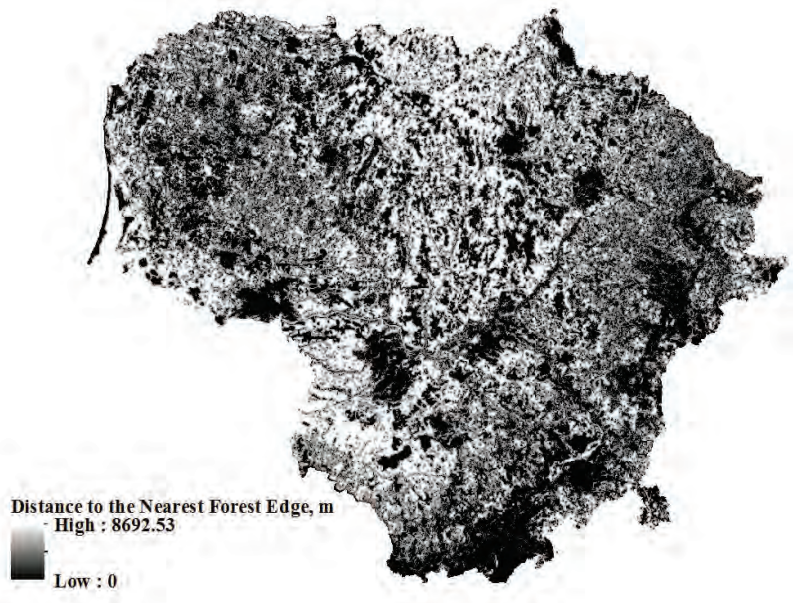

Figure 1. Forest distribution in Lithuania, representing grid of Euclidean distance of the cells to nearest forests.

Table 1

Forest distribution index in particular areas

Meteorological stations (MS)	Mean Euclidean distance to forests in particular areas, m							
	r_1 = 5 km	SD	r_2 = 10 km	SD	r_3 = 15 km	SD	r_4 = 20 km	SD
Biržų MS	493.4	415.7	352.9	359.1	368.4	392.7	346.2	375.9
Dotnuvos MS	498.7	406.2	393.9	408.5	408.8	402.1	379.9	400.9
Dūkšto MS	269.7	239.7	165.2	198.8	134.6	182.1	124.2	184.5
Kauno MS	252.0	261.5	300.3	398.7	304.9	378.3	327.1	405.2
Kybartų MS	1221.8	901.4	1389.0	1092.2	1039.7	1024.2	904.9	920.3
Klaipėdos MS	735.2	581.1	474.7	486.4	413.5	428.8	366.1	417.3
Laukuvos MS	185.7	176.0	154.4	163.4	154.2	174.0	147.7	179.5
Lazdijų MS	350.5	313.1	238.7	244.3	272.9	300.7	289.7	314.9
Panevėžio MS	507.9	570.4	360.9	434.9	344.5	440.7	316.2	401.4
Raseinių MS	675.8	463.5	377.7	372.2	303.0	317.2	256.1	287.6
Šiaulių MS	400.1	422.9	340.7	380.2	399.4	433.6	438.5	452.9
Šilutės MS	444.6	470.8	478.8	552.5	498.6	567.8	619.1	845.8
Telšių MS	321.3	303.8	190.9	263.4	148.2	218.1	133.0	190.2
Ukmergės MS	546.5	698.4	450.5	509.0	354.4	424.2	307.1	384.7
Utenos MS	137.9	157.6	147.4	154.8	138.8	152.9	132.6	155.4
Varėnos MS	18.8	56.6	47.1	122.7	73.2	151.7	89.2	179.0
Vilniaus MS	190.8	223.7	166.2	214.4	165.1	232.4	161.5	240.7
Vėžaičių MS	264.8	293.9	216.2	258.6	201.3	259.1	231.9	310.6
Švenčionių MS	145.3	180.8	131.0	173.7	113.5	166.0	99.7	163.4
Alytaus MS	446.4	326.4	404.9	358.2	364.6	360.2	335.5	386.3
Marijampolės MS	1464.1	764.7	943.2	738.1	783.2	702.3	661.0	669.7
N.Akmenės MS	271.6	289.4	289.5	297.4	263.3	288.5	247.5	293.4
Radviliškio MS	542.3	462.5	356.9	379.3	353.9	358.7	342.9	356.4
Rokiškio MS	232.4	224.0	162.4	186.3	160.3	186.9	164.3	184.8
Tauragės MS	316.0	304.4	208.3	278.0	170.3	255.3	190.0	293.1
Pasvalio MS	537.3	407.3	461.2	385.9	458.7	390.0	469.5	404.5
Skuodo MS	296.7	272.0	288.9	295.7	252.5	268.0	224.3	241.7
Jonavos MS	247.7	324.3	211.4	300.1	213.0	319.9	197.7	293.1
Liukonių MS	219.5	216.6	206.6	216.7	188.4	216.9	190.5	233.5
Birštono MS	119.3	147.8	119.3	177.3	226.3	299.5	263.9	318.1
Trakų MS	114.2	154.1	143.2	198.3	125.5	183.9	130.6	197.9

Note: $r_{1\text{-}4}$ = 5-20 km – forest coverage of the areas, surrounding meteorological station in 5, 10, 15, 20 km sized radius circles; SD – standard deviation.

studying the influence of formed by forest landscape roughness on precipitation.

Following assumptions from the results explaining are made – the shorter Euclidean distance to the nearest forest edge in the landscape, the greater amount of precipitation was accumulated. Significant adverse relationships between forest distribution index and the amount of precipitation during annual (January – December), spring (April – May) and even winter (December, January, February) periods suggests abundant precipitation in forested areas, where mean Euclidean distance to the forest is shorter. Adverse relationships between the amount of precipitation and forest distribution index was also found during summer (June – August) and vegetation period (May – September), but the relationships were week and statistically unreliable ($r = -0.195 – -0.352$, $p > 0.05$). The statement that the influence of forests on the amount of precipitation is weaker in summer (Maat et al., 2012) agreed well with our results. The obtained results may also be associated with the process of precipitation formation in summer. The development of convection forces over warm periods of the year quite often form powerful cumulous clouds, from which the torrential rain, highly distributed in the landscape, falls.

Findings have revealed that the amount of precipitation significantly increases ($r = -0.68$, $p < 0.05$) due to forest distribution, surrounding meteorological stations in 20 km radius buffers. It should be noted that in smaller areas, surrounding meteorological stations in 5 km, 10 km, 15 km radius

Table 2

Pearson correlation coefficients between precipitation and forest distribution index in particular areas

Parameters	Mean Euclidean distance to forest in particular areas, m			
	r_1= 5 km	r_2 = 10 km	r_3 = 15 km	r_4 = 20 km
Annual (January – December) amount of precipitation, mm				
r	**-0.359**	**-0.372**	**-0.421**	**-0.380**
p	**p = 0.047**	**p = 0.039**	**p = 0.018**	**p = 0.035**
Amount of precipitation in spring period (April – May), mm				
r	-0.352	-0.321	-0.346	**-0.368**
p	p = 0.052	p = 0.078	p = 0.056	**p = 0.042**
Amount of precipitation in summer period (June – August), mm				
r	-0.247	-0.233	-0.243	-0.195
p	p = 0.181	p = 0.207	p = 0.187	p = 0.292
Amount of precipitation in vegetation period (May – September), mm				
r	-0.320	-0.301	-0.341	-0.303
p	p = 0.080	p = 0.100	p = 0.060	p = 0.098
Amount of precipitation in winter period (December, January, February), mm				
r	-0.339	-0.336	**-0.400**	**-0.376**
p	p = 0.062	p = 0.064	**p = 0.026**	**p = 0.037**

Note: r_{1-4} = 5-20 km – forest coverage of the areas, surrounding meteorological station in 5, 10, 15, 20 km sized radius circles. In the graphs correlation coefficients are presented above, p-values below; statistically significant ($p < 0.05$) relationships are marked in bold.

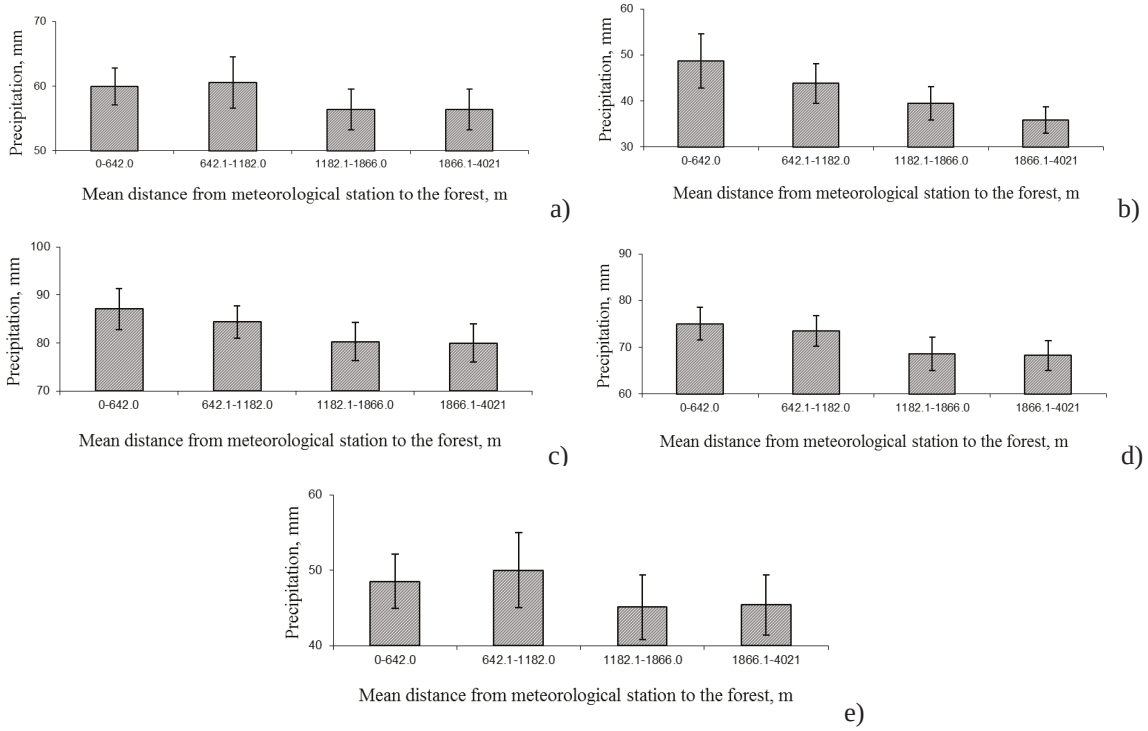

Figure 2. Effect of mean distance of meteorological station (MS) to the forest on a) annual (I-XII month); b) spring (IV–V month); c) summer (VI–VIII month); d) vegetation period (V–IX month); e) winter (I, II, XII month) precipitation amount.

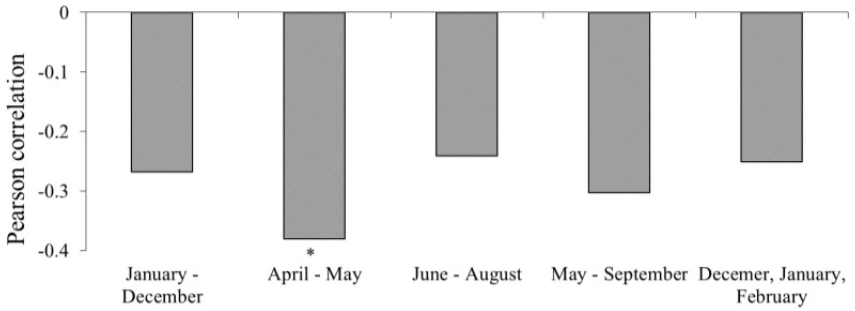

Figure 3. Pearson correlation between precipitation and mean distance of meteorological station to the forest during particular periods. Significant relationships ($p < 0.05$) marked with an asterisk.

Table 3

Pearson correlation coefficients between precipitation and forest perimeter per area ratio (PAR) in particular areas

Parameters	Forests perimeter per area ratio (PAR), m km^{-2}			
	r_1 = 5 km	r_2 = 10 km	r_3 = 15 km	r_4 = 20 km
Annual (January – December) amount of precipitation, mm				
r	0.326	**0.368**	**0.405**	**0.366**
p	p = 0.073	**p = 0.042**	**p = 0.024**	**p = 0.043**
Amount of precipitation in spring period (April – May), mm				
r	**0.551**	**0.490**	**0.490**	**0.505**
p	**p = 0.001**	**p = 0.005**	**p = 0.005**	**p = 0.004**
Amount of precipitation in summer period (June – August), mm				
r	0.355	0.343	0.330	0.278
p	p = 0.050	p = 0.059	p = 0.070	p = 0.130
Amount of precipitation in vegetation period (May – September), mm				
r	**0.427**	**0.427**	**0.455**	**0.427**
p	**p = 0.016**	**p = 0.016**	**p = 0.010**	**p = 0.017**
Amount of precipitation in winter period (December, January, February), mm				
r	0.274	0.323	**0.359**	0.319
p	p = 0.137	p = 0.076	**p = 0.047**	p = 0.080

Note: $r_{1\text{-}4}$ = 5-20 km – forest coverage of the areas, surrounding meteorological station in 5, 10, 15, 20 km sized radius circles. In the graphs correlation coefficients are presented above, p-values below; statistically significant ($p < 0.05$) relationships are marked in bold.

buffers, the value of forest distribution index is higher because of the location of meteorological stations in the landscape – most of the meteorological stations are established near or in urbanized areas. Therefore, significant relationships between the amount of spring (April – May) precipitation and forest distribution index obtained from areas, surrounding meteorological stations in 20 km radius buffers suggests further assumption – the more forest tracts or the more identical is forested area in the landscape, the higher is the amount of precipitation in the countryside. Parallel explanations are derived analyzing significant relationships ($r = -0.359$ – -0.421), $p < 0.05$) between the amount of annual (January – December) precipitation and forest distribution index. Significant relationship ($r = -0.376$ – -0.400, $p < 0.05$) between the amount of winter (December, January, February) precipitation and forest distribution index suggests the argument of landscape roughness formed by forests, thus enabling precipitation, as vegetation period is over and transpiration expired.

Direct impact of landscape roughness on the amount of precipitation is defined by the analysis of meteorological stations in the neighborhood to forests. The tendency of the amount of precipitation increase due to closer distance to forests occurred assessing the influence on precipitation by mean distance of meteorological stations to forests divided by quartile values (Figure 2). Similar trends have been recorded during spring (April – May), summer (June – August) and vegetation period (May – September), although the trend of increase in the amount of precipitation over

annual (January – December) and winter (December, January, February) due to closer neighborhood of forest was not as pronounced.

A statistically significant adverse correlation ($r = -0.380$, $p < 0.05$) between mean distance of meteorological stations to forest edge and the amount of precipitation was recorded during spring (April – May) period (Figure 3). However, relationships between mean distance to forests and the amount of precipitation over the rest considered periods were also adverse, but statistically unreliable. Findings have approved the assumption appointed in earlier derived interpretation of the results – the amount of precipitation tended to be higher when the distance to the forest in the landscape was shorter.

Further study determined significant relationships between the amount of precipitation and another parameter of forest distribution in the landscape – forest perimeter per area ratio (PAR). Significant increase ($r = 0.359 – 0.551$, $p < 0.05$) in the amount of annual (January – December), spring (April – May), vegetation period (May – September) and winter (December, January, February) precipitation amount due to forest perimeter per area ratio was recorded (Table 3). Adverse relationships between the amount of precipitation and PAR were recorded during summer (June – August) as well, but relationships were weak and statistically unreliable ($r = 0.278 – 0.355$, $p > 0.05$).

Generalizing the results of this study, here could be made an assumption that landscape roughness formed by forest distribution contributes in increase of the amount of precipitation, thus confirming findings of most researchers working in this study field (Anthes, 1984; Avissar and Liu, 1996; Knox et al., 2011; Pauliukevičius and Kenstavičius, 1995; Wang et al., 2009).

Conclusions

1. The amount of precipitation significantly increases ($r = -0.421 – -0.359$, $p < 0.05$) regarding to shorter Euclidean distance to the nearest forest edge in particular landscapes of considered areas during the periods of spring (April – May), winter (December, January, February) and overall year (January – December).
2. Statistically significant relationship ($r = -0.380$, $p < 0.05$) was determined between the amount of precipitation during spring (April – May) period and mean distance of meteorological stations to the nearest forests. The tendency of the amount of precipitation increase due to closer distance of meteorological stations to the forests, were defined during spring (April – May), summer (June – August) and vegetation (May – September) periods, though trends during annual (January – December) and winter (December, January, February) periods were not as pronounced.
3. The amount of precipitation was significantly related ($r = 0.359 – 0.551$, $p < 0.05$) to higher density of the forests, treated as perimeter per area ratio (PAR), during the periods of spring (April – May), vegetation period (May – September), winter (December, January, February) and overall year (January – December).

References

1. Anthes R.A. (1984) Enhancement of convective precipitation by mesoscale variations in vegetative covering in semiarid regions. *National Centre of Atmospheric Research*, pp. 541 – 554.
2. Augustaitis A., Mozgeris G., Eigirdas M., Sajonas M. (2009) Color Infrared Aerial Images to Evaluate Tree Crown Defoliation. Rural development 2009: the fourth international scientific conference, 15-17 October, 2009, Akademija, Kaunas region, Lithuania: proceedings, 4, pp. 213 – 216.
3. Augustaitis A., Augustaitienė I., Kliučius A., Pivoras G., Šopauskienė D., Girgždienė R. (2010) The seasonal variability of air pollution effects on pine conditions under changing climates. *European Journal of Forest Research,* 129, pp. 431 – 441.
4. Augustaitis A., Bytnerowicz A., Paoletti E. (2014) Biological reactions of forests to climate change and air pollution. *Environmental Pollution,* 184, pp. 657 – 658.
5. Avissar R., Liu Y. (1996) Three-dimensional numerical study of shallow convective clouds and precipitation induced by land surface forcing. *Journal of Geophysical Research*, 101 (D3), pp. 7499 – 7518.
6. Avissar R., Werth D. (2005) Global hydroclimatological connections resulting from tropical deforestation. *Journal of Hydrometeorology*, 6, pp. 134 – 145.
7. Brown J.C. (1877) *Forest and moisture: or effects of forests on humidity of climate*. Edinburgh: Oliver and Boyd, 308 p.
8. Findell K.L., Knutson T.R. (2006) Weak simulated extratropical responses to complete tropical deforestation. *Journal of Climate*, 19, pp. 2835 – 2850.
9. Hasler N., Werth D., Avissar R. (2009) Effects of tropical deforestation on global hydroclimate: a multimodel ensemble analysis. *Journal of Climate,* 22, pp. 1124 – 1141

10. Hazen H.A. (1897) Forest and rainfall. *Proceedings of the American Forestry Congress, the 7th Annual Meeting*, Washington, DC, pp. 133 – 139.
11. Kittredge J. (1948) *Forest influences: the effects of woody vegetation on climate, water, and soil, with applications to the conservation of water and the control of floods and erosion. 1st ed*. New York: McGraw-Hill Book Co, 394 p.
12. Knox R., Bisht G., Wang J., Bras R. (2011) Precipitation variability over the forest-to-nonforest transiton in SouthWestern Amazonia. *Journal of Climate*, 24, pp. 2368 – 2377.
13. Lee S., Berbery E.H. (2012) Land Cover Change Effects on the Climate of the La Plata Basin. *Journal of Hydrometeorology*, 13 (1), pp. 84 – 102.
14. Maat H.W., Moors E.J., Hutjes R.W.A., Holtslag A.A.M., Dolman A.J. (2012) Exploring the impact of land cover and topography on rainfall maxima in The Netherlands. *Journal of Hydrometeorology*, 14(2), pp. 524 – 542.
15. Masaitis G., Mozgeris G., Augustaitis A. (2013) Spectral reflectance properties of healthy and stressed coniferous trees. *iForest-Biogeosciences and Forestry*, 6, pp. 30 – 36.
16. McGuffie K., Henderson-Sellers A., Zhang H., Durbridge T.B., Pitman A.J. (1995) Global climate sensitivity to tropical deforestation. *Global Planet Change*, 10, pp. 97 – 128.
17. Medvigy D., Walko R.L., Avissar R. (2011) Effects of deforestation on spatiotemporal distributions of precipitation in South America. *Journal of Climate*, 24 (8), pp. 2147 – 2163.
18. Negri A.J., Robert F.A., Xu L., Surratt J. (2004) The impact of Amazonian deforestation on dry season rainfall. *Journal of Climate*, 17, pp. 1306 – 1319.
19. Nobre C.A., Sellers P.J., Shukla J. (1991) Amazonian deforestation and regional climate change. *Journal of Climate*, 4, pp. 957 – 988.
20. Pauliukevičius G., Kenstavičius J. (1995) *Ekologiniai miškų teritorinio išdėstymo pagrindai (Basics of ecological forest distribution in the teritories)*. Vilnius: Geografijos institutas, 289 p. (in Lithuanian).
21. Raguotis A. (1973) Влияние лесов на сток рек Литовской ССР и Калининградской области (Influence of forests on runoff of the Lithuanian SSR and the Kaliningrad region). *LMŪMTI darbai*, 14, c. 189 – 194. (in Russian).
22. Rakhmanov V.V. (1963) Dependence of the amount of precipitation on the wooded area in the plains of the European USSR. *Meteorological & Geoastrophysical Abstracts*. 14, pp. 712 – 719.
23. Ruseckas J., Tiškutė-Memgaudienė D. (2013) Teritorijos miškingumo įtaka kritulių kiekiui (The influence of the forest coverage of territory on the precipitation). *Miškininkystė*. 1(73), pp. 19 – 30. (in Lithuanian).
24. Shukla J., Nobre C., Sellers P.J. (1990) Amazon deforestation and climate change. *Science*, 247, pp. 1322 – 1325.
25. Voldoire A., Royer J.F. (2005) Climate sensitivity to tropical land surface chantes with coupled versus prescribed SSTs. *Climate Dynamics*, 24, pp. 843 – 862.
26. Wang J., Bras R.L., Eltahir E.A.B. (2000) The impact of observed deforestation on the mesoscale distribution of rainfall and clouds in Amazonia. *Journal of Hydrometeorology*, 1, pp. 267 – 286.
27. Wang J., Chagnon F., Williams E., Betts A.K., Renno N.O., Machado L.A.T., Bisht G., Knox R., Bras R.L. (2009) Impact of deforestation in the Amazon basin on cloud. *Climatology*, 106(10), pp. 3670 – 3674.
28. Werth D., Avissar R. (2002) The local and global effects of Amazon deforestation. *Journal of Geophysical Research*, 107 p.
29. Zhang H., Henderson-Sellers A., McGuffie K. (1996a) Impacts of tropical deforestation. Part I: Process analysis of local climatic change. *Journal of Climate*, 9, pp. 1497 – 1517.
30. Zhang H., Henderson-Sellers A., McGuffie K. (1996b) Impacts of tropical deforestation. Part II: the role of large-scale dynamics. *Journal of Climate*, 9, pp. 2498 – 2521.
31. Zon R. (1927) *Forest and water in the light of the scientific investigation*. Washington: U.S. Government Printing Office, 106 p.

CHANGES OF DOMINANT TREE SPECIES AREAS OVER THE PAST CENTURY IN LITHUANIA: A MATHEMATICAL APPROACH

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Abstract
The changes of areas of eight tree species in Lithuania during the past century were analysed. Aiming to apply the different approaches in forest studies, the Exponential smoothing method for forecasting the changes of the tree areas for the 25 years was used. The data dating from 1922 was analyzed as a time series. The descending trend was identified for Scots pine *(Pinus sylvestris* L.) and European ash (*Fraxinus excelsior* L.) and increasing trend – for Norway spruce (*Picea abies* (L.) H. Karst.), common oak (*Quercus robur* L.), birch species (*Betula pubescens* Ehrh. and *Betula pendula* Roth), black alder (*Alnus glutinosa* (L.) Gaertn.), European aspen (*Populus tremula* L.) and grey alder (*Alnus incana* (L.) Moench). The Exponential Trend with Multiplicative Seasonality (ET-MS) model was fitted for almost all investigated tree species with exception of European ash. For the latter species, the Damped Trend with Multiplicative Seasonality (DT-MS) model was chosen. Mean absolute percentage error of the model in all cases did not exceed 2%.
Key words: tree species, areas, statistical analysis, mathematical forecast.

Introduction

Recently the changes of tree distribution, abundance and habitat boundaries have often been associated with the warming of the climate. Such forecasts can be found even for Lithuanian tree species (Lekevičius et al., 2011; Ozolinčius, 2012; Ozolinčius et al., 2014). According to the vegetation zones range projections, Lithuanian territory will still remain in the mixed forest zone over the next century (Gonzalez et al., 2010). As composition of the dominated tree species will not significantly change in the near future, we used other approach for the forecast of tree species areas ignoring the climate factor.

There are eight most dominated tree species in Lithuanian forests. These include both coniferous forest tree species, i.e. Scots pine *(Pinus sylvestris* L.) and Norway spruce (*Picea abies* (L.) H. Karst.), and deciduous species, i.e. common oak (*Quercus robur* L.), European ash (*Fraxinus excelsior* L.), birch species (*Betula pubescens* Ehrh. and *Betula pendula* Roth), black alder (*Alnus glutinosa* (L.) Gaertn.), European aspen (*Populus tremula* L.) and grey alder (*Alnus incana* (L.) Moench). The stands of the mentioned tree species occupy almost 99% of all Lithuanian forests (Lietuvos miškų ūkio statistika, 2011). The data of various tree composition in Lithuanian is available from 1922 to 2012 and are given as irregulary observed time series.

There are various methods to forecast time series behaviour: different smoothing methods (moving average, exponential smoothing etc.), ARMA–ARCH and their modifications (ARIMA, SARIMA, VAR, VARMAX etc.), simulation of stochastic processes, neural networks (Zhang and Qi, 2005), etc. A vector autoregression (VAR) method is used when we can identify some endogenous and exogenous variables, which influences time series behaviour, i.e. abiotic (climate change, temperature, precipitation etc) and biotic (insect, fungi damages) factors. The simplest, from the mentioned above, is a smoothing method. The exponential smoothing and its modifications are mostly used for the forecasting time series. This simple method is based on the idea that the last data observed is more important than that from far history (Brown, 1956; Holt, 1957). Most of modifications are focusing on the fact if a trend, seasonality/periodicity and some irregular fluctuations are observed. Scientific literature is rich with applications of this method in different areas: economics/management (Bermúdez et al., 2008), transportation (Grubb et al., 2001), operational research (Taylor, 2003). However, we did not succeed in finding any published material where the Exponential smoothing method was used in the forest research.

In this paper we use models with a damped trend and multiplicative seasonality (DT-MS), and the exponential trend with multiplicative seasonality (ET-MS). Damped trend models are used for time series which exhibit a descending trend in some forecast horizon (Hyndman et al., 2008). Exponential trend models better fit series which are more likely increasing in a long time horizon (Hyndman et al., 2008). The multiplicative seasonality/periodicity is used in cases if time series exhibits the seasonal/periodical behaviour with a different amplitude (Gardner, 1985; Chatfield et al., 1988).

The aim of the study was to analyse and forecast the changes of forest tree species in Lithuania and to create the most suitable mathematical models.

Materials and Methods

The study area was the teritorry of Lithuania located in the Northern Europe and covering an area of 65,200 km^2.

To assess the individual tree species distribution and forest species composition trends in Lithuania during the last century, data from literature and Forest statistics of various editions since 1932 were analyzed: Lithuanian Statistical Yearbook (Lietuvos statistikos metraštis, 1932; 1939); Forest management of Lithuanian SSR (Lietuvos TSR Miškų ūkis, 1971); Production operating indicators of Forest enterprises (Miškų įmonių gamybinės veiklos rodikliai, 1976; 1981; 1990); Forestry production operating indicators (Miškų ūkio įmonių 1990 m. ir 1986–1990 m. suvestiniai gamybinės veiklos rodikliai, 1991) and the Forest statistics (Miškų statistika NMI, 2002) for the recent decades, i.e. the data from 1998 to 2012. Field research methodology was described in detail in fieldwork instructions (Kuliešis ir kt., 2005).

For the forecast of the tree species areas and the changes of forest species composition during the next 25 years, regardless of the climate parameters, we used the Exponential smoothing with the multiplicative seasonality/periodicity (length of the seasonal cycle p=12 years) (Table 1).

Here α specifies the constant (non-seasonal, non-trend) smoothing; δ specifies the seasonal smoothing (applicable only to analyses that include a seasonal component); ϕ specifies trend smoothing (applicable to damped trend models); γ specifies trend smoothing (applicable to linear and exponential trend models,

Table 1

Model characteristics

	Damped Trend, Multiplicative Seasonality Model (DT-MS)	Exponential Trend, Multiplicative Seasonality Model (ET-MS)
General equation of the model	$X_t = (b_0 b_1^t) I_t + \varepsilon_t$	$X_t = (b_0 + b_1 \phi t) I_t + \varepsilon_t$
Initial values of the model	$\hat{X}_0 = (S_0 T_0) I_{1-p}$, $T_0 = \exp\left(\frac{\ln m_2 - \ln m_1}{k-1}\right)$, $S_0 = \exp\left(\ln m_1 - \frac{p \ln T_0}{2}\right)$ here m_2 is the mean for the second seasonal cycle, m_1 is the mean for the first seasonal cycle, p is the length of the seasonal cycle	$\hat{X}_0 = (S_0 + \phi T_0) I_{1-p}$, $T_0 = \frac{m_k - m_1}{(k-1)p\phi}$, $S_0 = m_1 - \frac{pT_0\phi}{2}$, here k is the number of complete seasonal cycles, m_k is the mean for the last seasonal cycle, m_1 is the mean for the first seasonal cycle, p is the length of the seasonal cycle.
Smoothed value of the series at time t	$S_t = S_{t-1} T_{t-1} + \alpha \frac{\varepsilon_t}{I_{t-p}}$	$S_t = S_{t-1} + \phi T_{t-1} + \alpha(2-\alpha)\frac{\varepsilon_t}{I_{t-p}}$
Trend component at time t	$T_t = T_{t-1} + \alpha\gamma \frac{\varepsilon_t}{I_{t-p} S_{t-1}}$	$T_t = \phi T_{t-1} + \alpha(\alpha - \phi + 1)\frac{\varepsilon_t}{I_{t-p}}$
Smoothed seasonal factor at time t	$I_t = I_{t-p} + (1-\alpha)\delta \frac{\varepsilon_t}{S_t}$	$I_t = I_{t-p} + (1-\alpha(2-\alpha))\delta \frac{\varepsilon_t}{S_t}$
Forecast function	$\hat{X}_t = (S_t T_t) I_{t-p+1}$	$\hat{X}_t = (S_t + \phi T_t) I_{t-p+1}$

and for damped trend models without seasonality); S_0 is a smoothed value of the series at initial time; T_0 is an initial trend component, $\varepsilon_t = Y_t - \hat{X}_t$ is a residual. The length of the seasonal cycle p=12 years was selected automatically (naïve method, see the discussion section for details).

All model parameters are estimated by the least squares method using EXCEL and the STATISTICA software package. For the data analysis we used standard mathematical-statistical methods.

Results and Discussion

To clarify the changes of Lithuanian forest tree species composition in the recent decades, we analyzed the data from the year 1922. We found significant changes in the forest species composition over the past 90 years in Lithuania (Table 2).

According to the raw data (the data sampled in decades were shown in Table 2), we identified the tree species with a descending trend for Scots pine and European ash and an increasing trend for other species. For each species, depending on the specifics of the trend, we estimated (using the least squares method) parameters of the Damped Trend, Multiplicative Seasonality Model (DT-MS) and Exponential Trend, Multiplicative Seasonality Model (ET-MS) (Table 3). The best model was selected automatically by STATISTICA software by comparing SSE and MAPE errors of different models.

The results given in Table 3 showed that if δ was zero (Scots pine, black alder and European ash), a constant unchanging seasonal component was used to generate the one-step-ahead forecasts. If the δ parameter was equal to 1 (Norway spruce, common oak, silver birch and European aspen), then the seasonal component was modified "maximally" at every step by the respective forecast error times some function depending on α. In most cases, when seasonality was present in the time series, the optimum δ parameter was between 0 and 1 (grey alder).

Mean absolute percentage error of the model in all cases did not exceed 2% (Table 3). Using the above-mentioned parameters, we developed a mathematical forecast model for each tree species (see Table 1). For almost all investigated coniferous and deciduous tree species we fitted the model Exponential Trend, Multiplicative Seasonality (ET-MS). For European ash, according to the nature of changes and the mean absolute percentage error, the model Damped Trend, Multiplicative Seasonality (DT-MS) was chosen.

Table 2

Area of forest tree species in 1922 – 2012 (%)

Forest type	Assessment year									
	1922	1931	1941	1953	1961	1972	1983	1988	2002	2012
Scots pine	37.0	36.3	41.5	42.9	45.9	45.2	43.3	43.0	36.7	35.1
Norway spruce	35.4	36.5	30.3	27.3	20.2	17.9	20.7	23.0	23.1	20.8
Silver birch	12.2	12.1	11.2	13.5	16.6	19.6	21.3	20.1	19.9	22.3
black alder	5.2	5.5	5.9	5.5	5.9	5.5	5.1	5.0	6.0	6.9
grey alder	1.4	1.5	1.4	1.8	2.3	3.1	2.4	1.9	6.2	6.3
European ash	6.7	5.9	7.8	7.0	6.6	6.0	3.9	3.1	2.8	3.8
common oak	1.3	1.4	0.9	1.1	1.4	1.2	1.2	1.3	1.8	2.0
European aspen	0.8	0.8	0.9	0.9	1.1	1.3	1.9	2.5	2.7	1.7

Table 3

Model parameters

Forest type	Model parameters							Model error, MAPE (%)
	model	α	δ	ϕ	γ	T_0	S_0	
Scots pine	ET-MS	0.872	0.00	0.777	-	0.0147	36.47	0.43
Norway spruce	ET-MS	0.923	1.00	0.992	-	-0.181	37.05	0.69
common oak	ET-MS	0.945	1.00	0.927	-	0.0063	1.316	1.43
European ash	DT-MS	1.00	0.00	-	0.256	1.009	0.7637	1.65
Silver birch	ET-MS	0.938	1.00	0.950	-	0.1152	11.45	0.69
black alder	ET-MS	0.716	0.00	0.723	-	0.0088	5.347	0.88
European aspen	ET-MS	0.882	1.00	0.810	-	-0.059	6.670	0.97
grey alder	ET-MS	0.832	0.698	0.920	-	0.0642	1.073	1.84

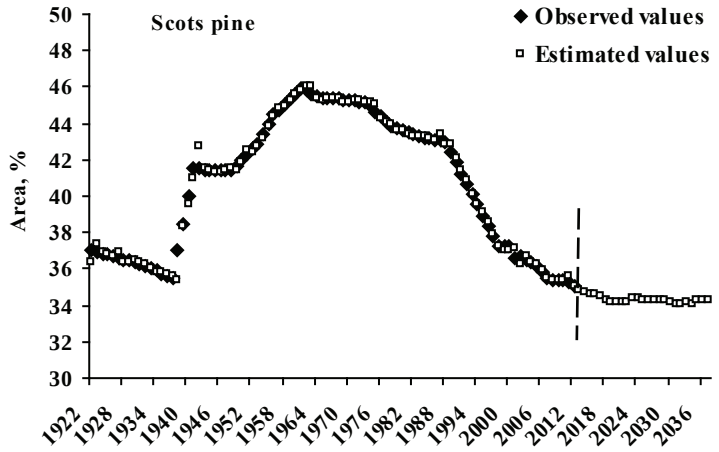

Figure 1. The area of Scots pine stands during 1922 – 2012 and forecast until 2037 (ET-MS model).

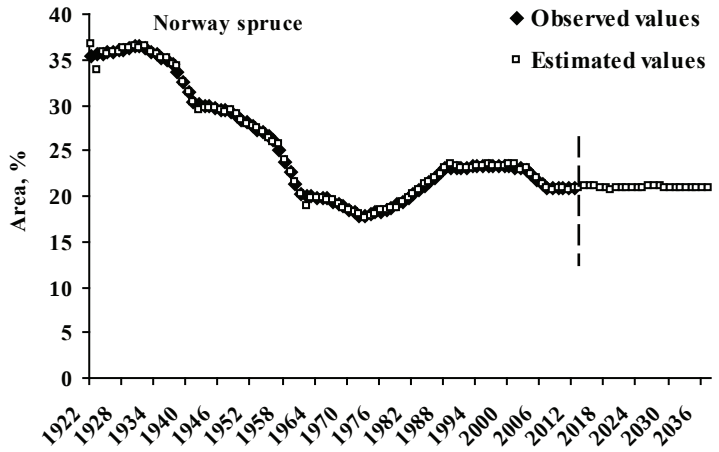

Figure 2. The area of Norway pine stands during 1922 – 2012 and forecast until 2037 (ET-MS model).

During this period the areas of both growing coniferous tree species decreased in Lithuania, but still they are the dominant species in the forests (Table 2). In comparison with 1922 or 1932, the area of Norway spruce decreased about 1.7-1.8 times, or from 35.4% to 20.8%. Not as much as Norway spruce, Scots pine also declined, especially over the last 50 years.

By applying the exponential data smoothing method (the exponential smoothing with multiplicative seasonality/ periodicity), we conducted the forecast of Lithuanian forest tree species changes for the next 25 years, i.e. until 2037. Mathematical modelling showed that, in accordance with the 90-year trend of Scots pine and Norway spruce and under the current climatic conditions, the areas of coniferous tree species would continue to decrease but with a slower rate (Figure 1 and 2).

The area of dominant deciduous tree species, except for European aspen, increased within a 90-year period in Lithuania. The area of aspen was only 3.8% in 2012, while in the 1922 – 1972 year it was 6 – 7% (Table 2). The most significant decline of the aspen area was recorded in 1972-1982. Our forecasts for the nearest 20 years for this tree species were not very pessimistic. According to the Exponential Trend model, the area of aspen should not greatly decrease and stabilize at about 3.7 – 3.8% level.

The comparison of all deciduous tree species revealed that mainly the area of Silver birch (R^2 = 0.85), and grey alder (R^2 = 0.84) has increased since 1922. Birch covers the largest area among deciduous trees and its area consistently increased (Figure 3). Our forecast showed that a similar trend would be the same in the next 25 years, i.e. the area of birch stands would increase up to 24% in Lithuania (Figure 3).

Meanwhile, the area of grey alder was quite different in various years (data not shown). For example, the increasing trend was observed up to

1970. Later, from 1970 to 1990, the area of grey alder significantly decreased, while in the next 10-year period an obvious increase in this tree species was fixed again. Over the past decade, the area of grey alder stands remained relatively constant and was about 6.2 – 6.3%.

The areas of European ash and common oak also increased quite significantly (R^2 = 0.6-0.7) during the studied almost 100-year period but only the areas of oak stands expanded consistently. Our fitted model showed that the oak area is expected to increase by 0.1 – 0.2% until 2037 compared with 2012 and it should reach about 2.2%.

While until 1991 – 1992 the European ash was one of the healthiest tree species in Lithuania, and an obvious increase of ash area was still recorded until about 2000, but in the recent years this species has become the most damaged species (Stakėnas et al., 2013). Onset of massive ash damages and mortality could be caused by both, unfavourable hydroclimatic conditions and by invasions of fungus *Chalara fraxinea*. Our mathematical forecast was quite pessimistic for this tree species, even regardless the disease progression. Under the present conditions and if the trend remains the same, we see the greatest area decrease over the next 25 years if all tree species in Lithuania are compared (Figure 4).

A slight increase of black alder area was recorded in Lithuania during the past 90 years (Figure 5). Starting from 1922 – 1932 until 2012 it has increased by about 1.3 times (Table 2). The first increase was recorded in 1922 – 1950, later up to 1988 uneven changes were evident. The minimum area of black alder (5%) was found in 1988 and starting from this year up to now the increasing tendency still remains. Our forecast model shows that the area of black alder in the time period 2020 – 2030 will be about 7.4 – 7.5%, while in 2012 it was 6.9%.

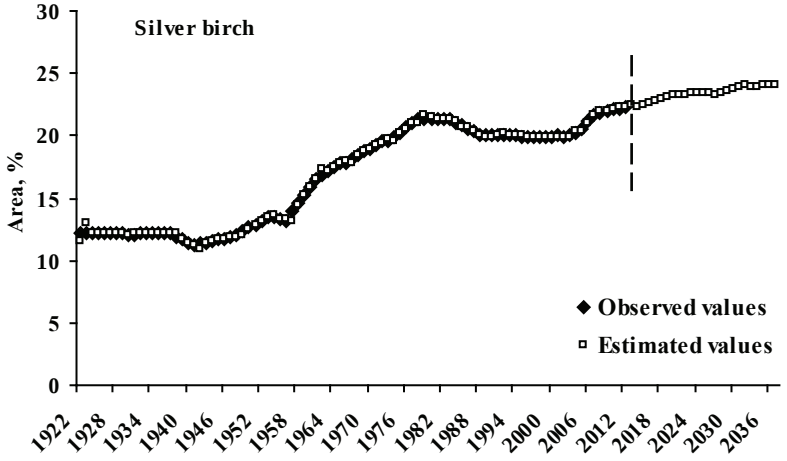

Figure 3. The area of Birch stands during 1922 – 2012 and forecast until 2037 (ET-MS model).

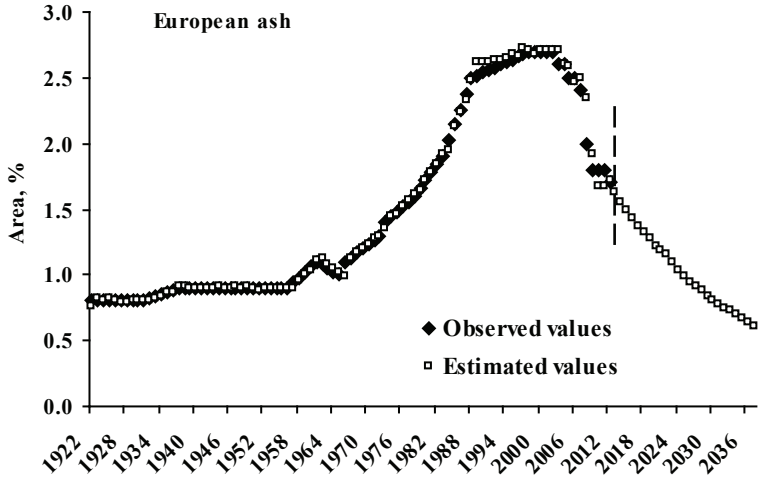

Figure 4. The area of European ash stands during 1922 – 2012 and forecast until 2037 (DT-MS model).

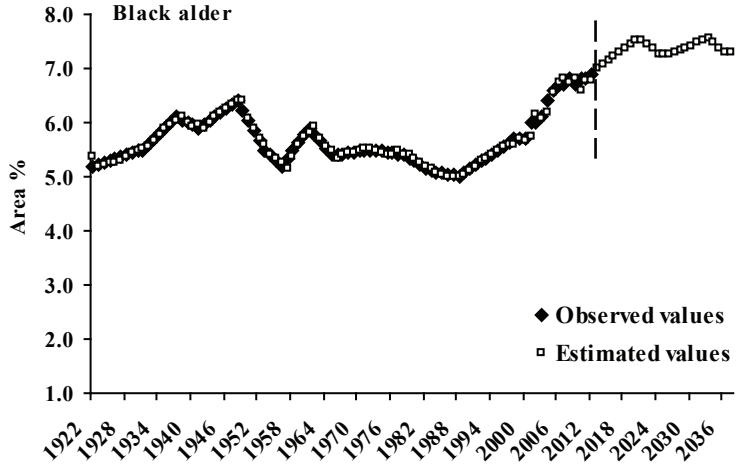

Figure 5. The area of black alder stands during 1922 – 2012 and forecast until 2037 (ET-MS model).

If compared black and grey alder, over the past 20 years the area of these two species was quite similar. The model estimates show that in the next 10-20 years the area of grey alder will be by 1% less than black alder.

We assumed that these analyses and forecasts could be important for the future forest management planning. From the scientific point of view, these results could be relevant aiming to reveal the reasons of forest tree species decline. However, we analysed and made the forecast for the actual published data (areas of the main tree species in Lithuania and their potential changes till 2036) and ignored the farming and reforestation specifics (policy) at various time periods. Many aspects could depend on the changes of forest subordination (a private, public or collective farm), the regulations and recovery (and/or the forest management) rules, as well as natural factors (invasions of *Ips typographus* and various tree diseases, wind damages, etc.). We did not take into account the potential effects of climate change and the effects of related biotic and abiotic factors on individual tree species. According to the mentioned reasons, it is possible, for example, that the decline of Norway spruce areas could be faster. In such cases we could use other econometrical forecast methods, i.e. the vector autoregression (VAR) method or its modifications. The calibration of length of the seasonal cycle *p* also may improve the forecast. The Census I and Census II or their modifications are usually used for this purpose.

Conclusions

1. The exponential trend with multiplicative seasonality (ET-MS) model was fitted for Scots pine, Norway spruce, common oak, Birch species, European aspen, black and grey alders, and the damped trend with multiplicative seasonality (DT-MS) model was chosen for European ash. Mean absolute percentage error of the model in all cases did not exceed 2%.
2. The study results showed that the areas of Scots pine and Norway spruce decreased in Lithuania over 90-year period and will continue to decrease in the next 25 years but at a slower rate.
3. The area of birch increased clearly and will continue to increase up to 24% in 2037. The area of oak expected to increase by 0.1 – 0.2% during the same period. The most pessimistic forecast was found for European ash (it will decrease to the level of 0.5%).
4. This forecast model could be further discussed and improved as the potential effects of climate change and other environmental factors were not included.

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References

1. Bermúdez J.D., Segura J.V., Vercher E. (2008) SIOPRED: a prediction and optimisation integrated system for demand. *TOP*, 16 (2), pp. 258 – 271.
2. Brown R.G. (1956) *Exponential Smoothing for Predicting Demand*. Arthur D. Little Inc., Cambridge, Massachusetts, USA, 15 p.

3. Chatfield C., Yar M. (1988) Holt-Winters Forecasting: Some Practical Issues. *Journal of the Royal Statistical Society. Series D (The Statistician)*, 37 (2), Special Issue: Statistical Forecasting and Decision-Making, pp. 129 – 140.
4. Gardner Jr.C.E.S. (1985) Exponential smoothing: The state of the art. *Journal of Forecasting,* 4 (1), pp. 1 – 28.
5. Gonzalez P., Neilson P.R., Lenihan J.M., Raymond J.D. (2010) Global patterns in the vulnerability of ecosystems to vegetation shifts due to climate change. *Global Ecology and Biogeography*, 19 (6), pp. 755 – 768.
6. Grubb H., Mason A. (2001) Long lead-time forecasting of UK air passengers by Holt–Winters methods with damped trend. *International Journal of Forecasting*, 17 (1), pp. 71 – 82.
7. Holt Ch.C. (1957) Forecasting Trends and Seasonal by Exponentially Weighted Averages. *Office of Naval Research Memorandum 52*. Reprinted in: Holt Ch.C. (2004) Forecasting Trends and Seasonal by Exponentially Weighted Averages. *International Journal of Forecasting*, 20 (1), pp. 5 – 10.
8. Hyndman R.J., Koehler A., Ord K. (2008) Forecasting with exponential smoothing: the state space approach. Springer-Verlag, Berlin, Germany, 362 p.
9. Kuliešis A., Kasperavičius A., Kulbokas G. (2005) *Nacionalinės miškų inventorizacijos darbo taisyklės* (Work rules of National forest inventory). Kaunas. 220 p. (in Lithuanian).
10. Lekevičius E., Ozolinčius R., Samas A. (2011) Modeling of temperate forest ecosystem's plasticity limits. *Ekologija*, 57 (1), pp. 1 – 11.
11. *Lietuvos statistikos metraštis* (Lithuanian Statistical Yearbook) (1939) Raidė, Kaunas, Lithuania, 297 p. (in Lithuanian).
12. *Lietuvos miškų ūkio statistika* (Lithuanian Forest statistics) (2011) Available at: http://www.amvmt.lt/2012/ST2012.aspx?&MID=0&AMID=731, 29 December 2013.
13. *Lietuvos statistikos metraštis* (Lithuanian Statistical Yearbook) (1932) Spindulys, Kaunas, Lithuania, 272 p. (in Lithuanian).
14. *Lietuvos TSR Miškų ūkis* (Forest management of Lithuanian SSR) (1971) Periodika, Vilnius, Lithuania, 273 p. (in Lithuanian).
15. *Miškų įmonių gamybinės veiklos rodikliai* (Production characteristics of Forest enterprises) (1976) Vilnius, Lithuania, 307 p. (in Lithuanian).
16. *Miškų įmonių gamybinės veiklos rodikliai* (Production characteristics of Forest enterprises) (1981) Vilnius, Lithuania, 278 p. (in Lithuanian).
17. *Miškų ūkio įmonių 1990 m. ir 1986–1990 m. suvestiniai gamybinės veiklos rodikliai* (Production characteristics of Forest enterprises in 1990 and 1986 – 1990) (1991) Vilnius, Lithuania, 96 p. (in Lithuanian).
18. *Miškų statistika NMI 2002* (Forest statistics NFI 2002) Available at: http://www.amvmt.lt/Images/Veikla/NMI/leidiniai/NMI%202003/12%206_ch_34.pdf, 29 December 2013.
19. Ozolinčius R. (2012) Possible effects of climate change on forest biodiversity, tree growth and condition: review of research in Lithuania. *Baltic Forestry*, 18 (1), pp. 156 – 167.
20. Ozolinčius R., Lekevičius E., Stakėnas V., Galvonaitė A., Samas A., Valiukas D. (2014) Lithuanian forests and climate change: possible effects on tree species composition. *European Journal of Forest Research,* 133 (1), pp. 51 – 60.
21. Stakėnas V., Beniušis R., Varnagirytė-Kabašinskienė I., Araminienė V., Žemaitis P., Čapkauskas G. (2013) Medžių būklės kaita Lietuvoje 1987–2012 metais (The changes of tree condition in Lithuania in 1989–2012). *Miškininkystė*, 1 (73), pp. 7 – 18. (in Lithuanian).
22. Taylor J.W. (2003) Short-term electricity demand forecasting using double seasonal exponential smoothing. *Journal of the Operational Research Society*, 54, pp. 799 – 805.
23. Taylor J.W. (2003) Exponential smoothing with a damped multiplicative trend. *International Journal of Forecasting,* 19 (4), pp. 715 – 725.
24. Zhang G.P., Qi M. (2005) Neural network forecasting for seasonal and trend time series. *European Journal of Operational Research*, 160 (2), pp. 501 – 514.

BIOTIC AND ANTHROPOGENIC RISK FACTORS IN NORWAY SPRUCE MIXED STANDS MANAGEMENT

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Abstract
Latvia is one of the forest-richest countries in Europe. Very often in young forest stands of spruce admixture of coniferous or deciduous trees are taking place. During the growth trees suffer from influence of different risk factors. Damages in mixed stands depend on chosen mode and intensity of economic activities. Forest management cannot be imagined without creating the infrastructure (roads, ditches, etc.). However, the development of infrastructure may cause an effect of fragmentation and lead to changes in the forest structure. The aim of the research is to analyze influence of forest spatial features on the sanitary state of mixed stands of spruce. In 2011 and 2012 mixed stands of spruce younger than 40 years were investigated in all regions of Latvia. Nineteen stands were measured and surveyed and 80 sample plots were arranged. With the help of Geographical Information System (GIS) data base of the State Forest Service of Latvia the forms of forest plots (regular or irregular), as well as location of neighboring infrastructural objects and location of mixed stands in forests were stated. In unnaturally created regular form plots damages of risk factors usually tend to be larger than in those, which have been created naturally. With the credibility of 95%, linear connection between occurrence of damages caused by browsing and intensity is relevant ($r=0.937 > r_{0.05}=0.575$), as well as occurrence and intensity of damages caused by *Lophophacidium hyperboreum* Lagerb. ($r=0.999 > r_{0.05}=0.575$).
Key words: regular plot form, forest array, spruce, mixed stands, risk factor.

Introduction

Latvia is considered to be one of the richest forest-growing countries in Europe, as forests occupy more than half of the state territory (State Forest Service, 2012a). According to forest monitoring data, total forest area in Latvia is 3497.08 thousand hectares, including 262.58 thousand hectares occupied by young forest stands of spruce (Statistical inventory of Latvian forest resources, 2010). Forest, as any other natural plant community, is usually determined by diversity of species. Forested areas of conifers, where initially only one tree species grows, often mix with other tree species and mixed spruce – deciduous stands develop (Gobakken and Næsset, 2002). The owners of the forest have to take into account that management of such stands will be different from treatment of pure conifer stands. Forest management should be done in a way that doesn't allow worsening of the sanitary state of forest, recognizing influence of risk factors in time.

However, it is not possible to escape from the influence of different risk factors in management of young forest stands. Each year trees are endangered by biotic factors like: insects, diseases, browsing, abiotic – frost, soil moisture, windfalls, snow throws, which influence the forest and stands lose their growth potential or even die (State Forest Service, 2012b). The most common reasons for damages in Latvian forests in 2012 were connected to human activities – 34.2%, insects – 23.0%, browsing – 21.2%, diseases caused by fungi – 11.7% and damages caused by abiotic factors – 7.6% (Statistical inventory of Latvian forest resources, 2012).

According to statistical data, human actions have the largest influence on the environment. Anthropogenic damages or those created by human in mixed stands depends on intensity of economic activities and management regime. Damages can be slightly broken branches of trees or small scratches of trunks, or intermediate cutting that has not been done in time. It happens that trying to increase profitability of the stand, too many trees are cut in a stand, which can leave a negative effect on the future productivity of stand. Manmade objects of infrastructure like roads, rides, drainage ditches, which are integral parts of the forest management, may influence neighboring stands in both ways - positively and negatively. That leads to the change of spatial specifics of the forest, as well as biotic interaction and dynamics of population (Marcantonio et al., 2013). Besides, infrastructural objects created by human cause fragmentation effect (Deldago et al., 2007). By changing the forest structure, also a spatial distribution of trees in mixed stands is changed. Natural (irregular) forest stand forms are replaced by artificial (regular) stand forms. However, using forest ecosystem for different goals, all possible measures should be taken not to worsen the sanitary state of the forests and not to spoil forest structure. To achieve this goal, forests have to be managed according to principles of sustainable forestry.

By surveying the sanitary state in mixed stands, it is possible to avoid the influence of different risk factors and by choosing appropriate management technique, to increase productivity of mixed stands. The aim of the research is to analyze the impact of biotic and anthropogenic risk factors in Norway

spruce mixed stands management. To achieve this aim, following tasks are set:

1. to analyze the impact of biotic risk factors on the sanitary state in mixed stands of spruce;

2. to analyze impact of anthropogenic risk factors on sanitary state of spruce.

Materials and Methods

The empirical data were measured in 19 mixed stands of spruce which were not older than 40 years. Collection of data was done two years - 2011 and 2012. In total 80 sample plots were set up. In Norway spruce mixed stands with admixture of birch, pine, oak, ash and gray alder following biotic damage was detected: spruce aphid *Elatobium abietinum* (Walker), spruce bud scale *Physokermes Piceae* Shrnk., little spruce sawfly *Pristiphora abietina* Crist., eastern spruce gall aphis *Sacchiphantes abietis* L., spruce bud moth *Zeiraphera ratzeburgiana* Sax., snow blight *Lophophacidium hyperboreus* Lagerb., spruce needle rust *Chrysomyxa abietis* (Wallr.) Ung., root rot *Heterobasidion annosum* (Fr.) Bref., browsing and abiotic damage like: snow crushes, snow breaks, frost and anthropogenic damages. Characterization of Norway spruce mixed young forests is given in Table 1.

The number of sample plots depends on area of forest plots. Rectangular plots that are located on the

Table 1

Characterization of Norway spruce mixed young forest stands

Research objects	Geographic coordinates (Lat; Lon)	Species composition	Forest site type	$D_{av.}$, cm	$H_{av.}$, m	Number of trees per hectare	Spatial shape
In 2011, 10 mixed young forest stands surveyed							
Jelgava 21/14	56.7318507; 23.7515365	$8E2B_6$	*Mercurialiosa mel.*	1.9	2.5	4100	not regular
Šķēde 9/2	57.2481950; 26.0649684	$8E1B1O_8$	*Oxalidosa*	1.9	2.6	2530	not regular
Šķēde 9/17(1)	4.4863337; 70.43398740	$7E3B_{17}+P_{17}$	*Oxalidosa*	9.1	10.4	1850	regular
Šķēde 19/20	57.2433051; 22.6840973	$8E2O_{23}$	*Hylocomiosa*	12.2	13.1	7800	regular
Šķēde 8/35(3)	57.2616275; 22.7677850	$7E3B_{17}+P_{17}$	*Oxalidosa*	14.7	15.7	3850	regular
Jelgava 187/9	56.7031988; 23.5668003	$9E1B_8$	*Myrtillosa turf. mel.*	3.0	3.0	2330	not regular
Jelgava 50/9	56.8329285; 23.6987532	$6E2Oz1B1P_9$	*Myrtillosa mel.*	3.6	3.4	1460	regular
Viesīte 1/4	56.4212798; 25.2995895	$7E2B1A_8$	*Oxalidosa*	2.7	3.6	5600	not regular
Līvbērze 176/3	56.4212798; 25.2995895	$8E2B_{10}$	*Myrtillosa turf. mel.*	1.8	2.7	5700	regular
Līvbērze 176/6	56.8221322; 23.6815388	$7E3B_9$	*Myrtillosa turf. mel.*	2.5	3.1	3700	regular
In 2012, 9 mixed young forest stands surveyed							
Rēzekne 77/11	56.4325759; 27.3941559	$9E_{14}1P_{14}$	*Hylocomiosa*	4.4	4.1	1050	regular
Rēzekne 74/13	56.4369605; 27.3899869	$8E_82P_8$	*Hylocomiosa*	2.5	2.8	5400	regular
Jelgava 115/9	56.5570359; 23.7085786	$8E_{36}1Ba_{21}1B_{21}$	*Oxalidosa*	12.2	13.9	2370	regular
Šķēde 70/16	57.2274421; 22.8481182	$9E1Oz_6$	*Oxalidosa*	4.6	5.2	5400	regular
Šķēde 8/20	57.2616796; 22.7575702	$9E1B_{11}$	*Oxalidosa*	7.0	6.5	2660	not regular
Šķēde 56/10	57.2382117; 22.8323237	$8E2P_{13}$	*Myrtillosa mel.*	3.1	3.8	3940	regular
Šķēde 57/19	57.2345296; 22.8392492	$6E3P_{27}1B_{21}$	*Hylocomiosa*	9.6	11.0	2620	regular
Jelgava 34/11	56.7224405; 23.7632981	$6E4P_{10}$	*Myrtillosa*	3.9	17.1	7700	regular
Šķēde 65/1	57.2328401; 22.8333715	$9E_{13}1P_{13}$	*Mercurialiosa mel.*	5.1	6.5	3470	regular

* $D_{av.}$ – average tree diameter, $H_{av.}$ – average tree height, number - the stand composition and age, E – *Picea abies* (L.) Karst., B – *Betula pendula* (Roth), A - *Populus tremula* L., P – *Pinus sylvestris* L., Oz - *Quercus robur* L., O - *Fraxinus excelsior* L., Bl - *Salix caprea* L., Ln - *Myrtillosa,* Mr - *Vacciniosa,* Dm – *Hylocomiosa*, Dms - *Myrtilloso-sphagnosa,* Vr - *Oxalidosa,* Vrs - *Myrtilloso- polytrichosa*, As - *Myrtillosa mel.,* Ks - *Myrtillosa turf. mel.,* Ap - *Mercurialiosa mel.*

Table 2

Damage degrees of biotic factors

Damage evaluation	Damage degree
Trees without indications of weakening or growth disturbances	0
Economically insignificant damages or faults (few broken branches, small stem damages)	1
Economically significant damages (trees with one or more small stem damages that do not exceed half of the stem diameter, etc.)	2
Highly damaged (damages of the central shoot of tree, it´s premature die-back; withered, broken top; stem of a tree is bent and cannot take a vertical position; tree with one or more stem damages where scars exceed half of stem diameter; visible resin galls on the whole length of tree stem)	3
Trees died in the current year (needles and leaves are yellow and brown)	4
Dead trees	5

diagonal or along transects, go through only a major density stands and cover the whole area of the forest. All plots were randomly selected, and most of them - were circular. The main indicator for choosing the type of sample plots was the average tree height of the stand. With the average tree height up to 12 m a 50 m^2 sample plots were created with a circle radius of 3.99 m, but in stands with average tree height H ≥ 12.0 m a sample plot of 200 m^2 with a 7.98 m radius were created (Rūba, 2012).

With the electric sliding calliper or simple calliper in sample plot diameter of each tree stem was measured at breast height with accuracy 1 mm, in this work were used. Average tree height was measured for 20-30 trees using measuring instrument VERTEX with accuracy 1 cm. The coordinates of each young growth were determined with a GPS device LKS-92 by transforming geographic coordinates (Rūba, 2012b).

Damages of biotic factors were divided into six damage degrees (Table 2).

To determine the number of trees per hectare, was used the following formula (1):

$$N = \frac{N_p \cdot 10000}{L}, \quad (1)$$

where N - number of trees per hectare after sample plot inventory data, pieces ha^{-1}, N_p - number of trees in the sample plot, pieces and L – area of sample plot, m^2.

Damage occurence proportion was calculated by using formula (2):

$$P = \frac{n \cdot 100}{N}, \quad (2)$$

where P - damage occurrence proportion, %, n - number of damaged trees, pieces ha^{-1} and N - total number of measured trees, pieces ha^{-1}.

Damage intensity was calculated by using formula (3):

$$R = \frac{\sum n_i b_i \cdot 100}{N \cdot k}, \quad (3)$$

where R - damage intensity, %, n_i – number of damaged trees, pieces ha^{-1}, b_i - degree of damage, N - total number of measured trees, pieces ha^{-1} and k - highest degree of damages (points) (Miezīte et al., 2013; Ruba et al., 2013).

To find out how young stands of Norway spruce are influenced by stands next to them, the location of stand in forest array was determined. Forest plot forms were found using the State Forest Service geographic information system (GIS) maps ArcGIS 9.1, 9.2 and 9.3 (Forest State service, 2007). Irregular forest plots were naturally formed, but regular were transformed by a human into triangular or rectangular forest plots. Correlation and regression analyses were used for finding out the relevance between the occurrence and intensity of damages. All mixed stands in this research were artificially restored. To perform data processing, stand heights were divided into 2 groups: 2.5 - 4.0 m and 4.1 m above. Spruce snow blight *Lophophacidium hyperboreus* Lagerb. damage was determined by characteristicl features - brown spots on infected needles, disease develops with colouring needles red-brown, later - tan grey and fall off. Eastern spruce gall aphis *Sacchiphantes abietis* L. was determined by oakgalls (up to 18 cm) on the Norway spruce shoots (ANNILA et al., 2006). Used methodology have already been tested and used in previous publications (Ruba et al., 2013a).

Results and Discussion

The impact of biotic factors on sanitary state of mixed stands of spruce

The most serious damages, due to which clear stands as well as mixed stands suffer from, are those caused by browsing. Insignificant damage is browsing caused by tearing off the bark, in such a way weakening trees, and causing slow down of growth

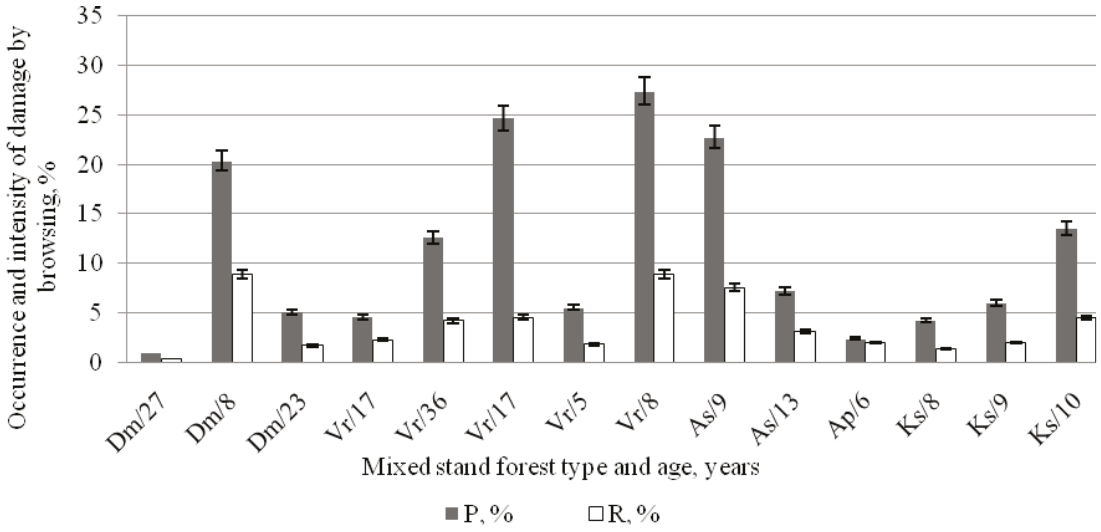

Figure 1. Occurrence and intensity of damages by browsing depending on the forest type and stand age (P – occurrence of damage; R – intensity of damage).

of them. As a result, also a tree increase declines, but more significant damages are caused by moose and red deer in sparse stands, breaking off main shoots of the tree, and as a result of it Norway spruce languish or even perish (Tauriņš, 1982). From 19 mixed stands of Norway spruce chosen randomly, damages of browsing were stated in 14 of them, but there were no such damages in others. Assessing the impact of risk factor of browsing, it was found out that less damage was in the mixed stands which in forest array were placed between two mature stands (Руба, 2012). Low indicators of damage intensity (0.3% – 2.0%) might be explained by the situation in forest array of mixed stands between gravel roads. Browsing repels the sand and dust landed on needles and leaves, hindering the ingestion of nutrients. As to the mostly damaged mixed stands, it has to be stressed, that there are several of them – Rēzekne 74/13, Viesīte 1/4, Jelgava 50/9 and Līvbērze 176/3. The incidence of damages in those stands varies between 4.5 – 9.0% (Fig. 1). Those indicators testify that damages caused are serious and browsing may be considered to be one of the most threatening biotic factors, which influence the sanitary state in researched objects negatively. One of the most damaged mixed stands is located in Rēzekne 74/13, which is 8 years old in *Hylocomiosa* forest type (occurrence of damage – 20.4%, intensity of damage – 9.0%).

The main species in stand is Norway spruce *Picea abies* (L.) Karst. in admixture with Scots pine *Pinus sylvestris* L. (20%). This forest stand is surrounded by middle-aged stands of Scots pine, road and amelioration ditch on the west side. High occurrence indicators of damages caused by browsing were in 8 years old mixed stand in Viesīte 1/4 (occurrence – 27.4%, intensity – 8.9%). The main species is Norway spruce (70%) with the admixture of birch *Betula Pendula* (Roth) and aspen *Populus tremula* L. in *Oxalidosa* forest type. The other damages caused by bud scale *Physokermes Piceae* Shrnk. and leaf beetle *Chrysomelidae* were detected in this stand which is surrounded by a ride, road, *Alnus incana* (L.) Moench maturity and Norway spruce young stands. High occurrence indicators (occurrence – 22.7%, intensity – 7.6%) were in mixed stand Jelgava 50/9. The main species is Norway spruce (60%) in admixture with oak *Fraxinus excelsior* L., birch, Scots pine, which are located on drained soil in *Myrtillosa mel.* In describing damaged mixed stands, it has to be stressed that most damages can be stated particularly in artificially made plots of regular form. Two of previously mentioned stands are stands of high density, where the number of trees in a hectare varies between 5400 and 5600 and they belong to the height group (2.6 – 4.0 m). During the research it was found out that there is a significant correlation between occurrence and intensity of browsing, while $r=0.937 > r_{0.01}=0.575$. In searching for correlation between occurrence and intensity of browsing by forest types and regions, the results of analysis of variance showed that there is no significant difference between forest types, while $p=0.187 > \alpha=0.05$, as well as there is no significant difference between regions of Zemgale, Kurzeme and Latgale, $p=0.079 > \alpha=0.05$.

The snow blight *Lophophacidium hyperboreum* Lagerb. is the second biotic risk factor which occurs in up to 40 years old forests in Latvia. Of course, it is mostly peculiar in the forests in Finland, though such damages were found in Latvia after a very snowy winter in 2010 and 2011. The needles, located under

the snow, were affected by the disease, sallow, became grey and fell off at the end. Climatic factors, when a large amount of snow falls in winter and trees are under the snow for a long time (Annila et al., 2006) could be mentioned as those that foster the prevalence of snow blight. The disease was found in mixed stands aged from 6 to 27 years in regions of Kurzeme and Latgale. The intensity of damages caused by snow blight is less than intensity of damages caused by browsing. Severely damaged needles (occurrence – 81.0%, intensity – 14.3%) were in 14 years old mixed stand Rēzekne 77/11 in *Hylocomiosa* and 13 years old mixed stand Šķēde 56/10 with Norway spruce as main species (80%) and (90%) in admixture with Scots pine in *Myrtillosa mel*. The damages caused by snow blight are larger in young forest stands, which are situated between seasoning stands in *Myrtillosa mel.*, and this research results coincide with the previous research results (Ruba et al., 2013). Meanwhile, insignificant damages were in 8 and 12 years old mixed stands with Norway spruce as leading species (80%) in admixture with Scots pine, which has artificially created forest plots and located in *Hylocomiosa* and *Mercurialiosa mel.* Lower indicators of occurrence and intensity of damages might be explained by location of mixed stands of Norway spruce between agricultural land, road and amelioration ditch in the forest array, where there were no trees around the stand and the disease spread slower. During the research it was proved that there is significant difference between occurrence and intensity of damages caused by snow blight $r=0.999 > r_{0.01}=0.575$. No significant difference was found between occurrence and intensity of damages by snow blight and forest types, $p=0.274 > \alpha=0.05$, as well as no significant difference between the regions of Latgale and Kurzeme, $p=0.391 > \alpha=0.05$.

As a third factor, which was found out in surveyed mixed stands of Norway spruce, is eastern spruce gall aphis *Sacchiphantes abietis* L. This is the pest, which sucks juices from the needles and damages shoots of the spruce, making yellow oakgalls (Annila et al., 2006). The damages of this pest are insignificant in mixed stands because occurrence of damages does not exceed 3.5% and intensity – 3.0%. Assessing the indicators of damages done by other insects (see Materials and Methods) it can be affirmed that entomological factors do not affect the sanitary condition in surveyed mixed stands.

The impact of anthropogenic risk factors on the sanitary state of spruce

Besides biotic factors the sanitary state in the forests is mostly influenced by anthropogenic actions of a human in the process of carrying out different actions of forest management in young stands, such as changing natural – irregular form plots to regular form plots, changing the specifics of the forest. Striving for the merits of the forest, the human disarranges natural balance of processes and changes the dynamics of spatial structure of mixed stands. Through the influence of anthropogenic factors, the changes in the forest specifics might not result immediately, or might be insignificant, but they will show up after a longer time. That is why it is important to think about maintaining scenery of the forest before planning any actions (Baskent, 1999). During this research it was found out that damage by browsing increased in the stands, which are higher than 2 meters. Forest owners often did not provide repellents; as a result, the damage intensity increased thus worsening the health state in mixed stands of the Norway spruce. More damage was caused by browsing found in the regular form plot forests by the number of trees 5400 – 5600 and height group of 2.6 – 4.0 m, where as dominant tree species (60 – 80%) is Norway spruce in admixture with oak (20%), birch (20-30%) and Norway spruce (80 – 90%) in admixture with Scots pine (20%) in forest types of *Oxalidosa*, *Hylocomiosa* and *Myrtillosa turf. mel.* which are located between infrastructural objects, young forest stands of Norway spruce and middle-aged stands of Scots pine. Less damages were detected in regular and irregular form plots by tree number, which is the closest to the optimal 2330 – 3700 and the height group 2.6 – 4.0 m and over 4.1 m with the Norway spruce as the dominant tree species (60 – 90%) in admixture with birch (10 – 30%) and Scots pine (30%). Assessing damages caused by snow blight in mixed stands, it was stated that the most significant were those in forests of regular form plots by the number of the trees 1050-3940 and height groups 2.6-4.0 m and above 4.1 m with the Norway spruce as predominant tree species (80-90%) in admixture with Scots pine (10 – 20%), which were surrounded by Scots pine and birch young forest stands, amelioration ditches and maturity stands of Scots pine. At the same time, insignificant damages were in regular form plots by the tree number of 3470-5400 on hectare at the height group 2.5 – 4.0 m and above 4.1 m with Norway spruce as predominant tree species (80 – 90%) with admixture of Scots pine (10 – 20%) which are surrounded by middle-aged Scots pine stands, agricultural land, amelioration objects and young forest stand of Norway spruce. However, improvements of the state of mixed stands may be achieved by the help of thinning, regulating the pace of tree growth in the preferred direction to get wood of high quality in future. Making of contents of stands helps to create the preferred content and thickness of future tree species. From the mixed stands surveyed, 4% was with the height group of 2.6 – 4.0 m and 5% with height above 4.1 m, where the total number of

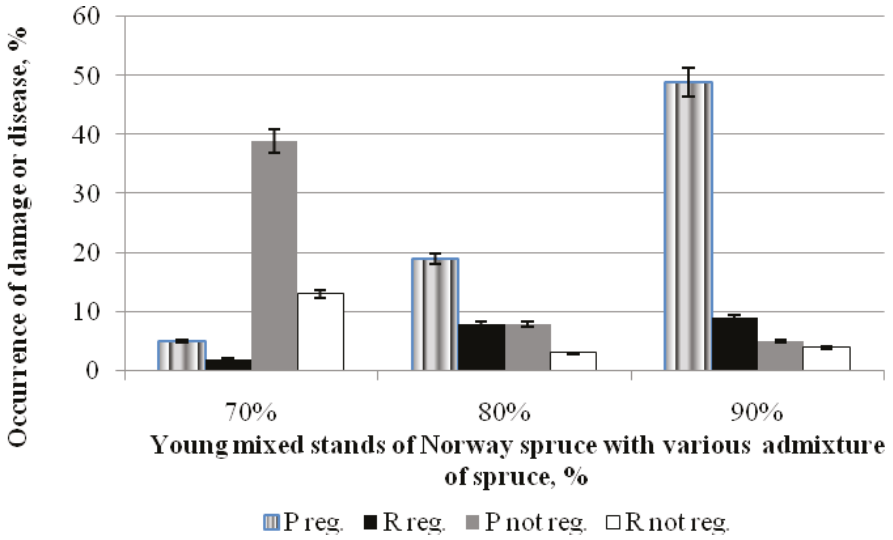

Figure 2. Biotic and anthropogenic risk factor occurrence and intensity in young mixed stands of Norway spruce with various admixture of spruce.

trees on hectare varies between 1050 and 7800 on hectare, which means that half of them need thinning. Thinning is usually carried out, when the average height of trees is bigger than 2 m (Regulations of Latvian Cabinet of Ministers No. 935, 2013) and the trees of particular species, which interfere the growth of dominant species are cut down. If damages caused by browsing are detected in the stands, thinning starts later, when trees reach 3-4 meters in height. Thinning can help improve the health status of forest stands, the rate of tree growth, reduce the competition between other trees, thus, improving the availability of nutrients, water and sun resources (Larsons, 1969). The optimal tree number after thinning is 1400 to 2000 on hectare in mixed stands of Norway spruce and deciduous trees (Grīnvalds et al., 2008). Conclusions about the optimal number of trees in stands cannot be done yet, while in only two stands the number of trees varies between 1460 and 1850, in turn, others need thinning. However, questions about the optimal tree species in the admixture species, which would give the largest amount of wood, is still being considered by the scientists (Krastiņš, 1981). Productivity in mixed Norway spruce and birch stands is higher than in pure stands (Frivold, 1982). The results of research coincide with the theory, stating that mixed stands of spruce have several advantages in comparison to clear stands. Judged by the research done previously and now about the sanitary state in clear stands and mixed stands, it would be advisable to grow mixed stands of spruce, because the intensity of biotic damages stated in clear stands is much higher than that in mixed stands. For example, the intensity of browsing reaches 0.8 – 20.2%, accordingly in mixed stands 0.3 – 0.9%, also intensity of damages caused by snow blight differs in clear stands (0.2% – 18.8%), while in mixed stands it is lower 0.2 – 14.3% (Ruba et al., 2013b). Such disease like root rot *Heterobasidion annosum* (Fr.) Bref., was found in clear stands on height group above 4 m with intensity of 0.3 – 17.2%, but in this research it was detected only in one stand, and it was not influenced by the sanitary state in mixed forests in Latvia.

There is no significant difference between biotic and anthropogenic risk factors occurrence and intensity in young mixed stands of Norway spruce with various admixture of spruce (70, 80, 90%) depending on the forest plot form (regular and irregular), $p=0.413 > \alpha=0.05$ (Fig.2).

During the research it was found out that difference between occurrence of damage and height groups (see Materials and Methods) is no significant ($p=0.086 > \alpha=0.05$). Similarly, there is no significant difference between damage intensity ($p=0.361 > \alpha=0.05$). It follows that forest managers should maintain the natural shape of the compartment (irregular), as much as possible. To provide the conservation of the spatial structure of the forest and not to cause worsening of sanitary state in mixed stands, it is not necessary to stop forest management actions (Bells and Nikodemus, 2000), but it is necessary to assess the methods of forest management.

Conclusions

1. Two main risk factors that most negatively affect the sanitary conditions in forests in Latvia are browsing and *Lophophacidium hyperboreu* Lagerb.
2. There is no significant difference between biotic and anthropogenic risk factors occurrence and

intensity in young mixed stands of Norway spruce with various admixture of spruce (70, 80, 90%) depending on the forest plot form (regular and irregular), $p=0.413 > \alpha=0.05$.

3. Sanitary condition in forests is often worsened by forest owners, because they do not protect mixed young forest stands which are higher than 2 m from browsing. As a result, it leads to higher browsing damage intensity.

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References

1. Annila E., Kytö M., Lilja A., Lilja S., Kurkeela T. (2006) *Kaitēkļu slimības kokaudzētavās* (Pest Damages in Ttree Nurseries). AS Latvijas valsts meži, 136. lpp. (in Latvian).
2. Baskent E. (1999) Controlling spatial structure of forested landscapes: a case study towards landscape management. *Landscape Ecology*, 14, pp. 83 – 97.
3. Bells S., Nikodemus O. (2000) *Meža ainavas plānošanai un dizainam* (Forest Landscape for Planning and Design). R.: Valsts meža dienests. 75 lpp. (in Latvian).
4. Delgado J.D., Arroyo N.L., Arévalo J.R., Fernández-Palacios J.M. (2007) Edge Effects of Roads on Temperature, Light, Canopy Cover, and Canopy Height in Laurel and Pine Forests (Tenerife, Canary Islands). *Landscape and Urban Planning*, 81, pp. 328 – 340.
5. Frivold L. (1982) Bestandsstruktur og produksjon i blandingsskog av björk (Betula verrucosa Ehrh.) og gran (Picea abies (L) Karst.) i sydost-Norge (Summary: Stand structure and yield of mixed stands of birch (Betula verrucosa Ehrh.) and spruce (Picea abies (L) Karst.) in southeast Norway). *Meldinger fra Norges Lantbrukshögskole*, 90, 108 p. (in Norwegian).
6. Gobakken T., Næsset E. (2002) Spruce diameter growth in young mixed stands of Norway spruce (*Picea abies* (L.) Karst.) and birch (*Betula pendula* Roth B. *pubescens* Ehrh.). *Forest Ecology and Management*, 171, pp. 297 – 308.
7. Grīnvalds A., Linde E., Gercāns J., Neicinieks M., Šica L., Brauners I., Gaigals M. (2008) *Kopšanas ciršu rokasgrāmata* (The Thinnings Guide). Latvijas valsts meži, 108 lpp. (in Latvian).
8. Krastiņš M. (1981) Bērzu piemistrojums egļu vēra audzēs (Birch Admixture of Spruce Stands in Forest Type *Oxalidosa*). *Mežsaimniecība un mežrūpniecība*, 6, 20 – 23. lpp. (in Latvian).
9. Larson P.R. (1969) *Wood Formation and the Concept of the Wood Quality*. Bull. Yale School For. 74, pp. 1 – 54.
10. Regulations of Latvian Cabinet of Ministers No. 935 (2013) Noteikumi par koku ciršanu meža zemēs (Regulations of Trees Cutting in Forest Lands). Available at: www.likumi.lv, 29 February 2014. (in Latvian).
11. Marcantonio M., Rocchini D., Geri F., Bacaro G., Amici V. (2013) Biodiversity, roads, & landscape fragmentation: Two Mediterranean cases. *Applied Geography,* 42, pp. 63 – 72.
12. Miezite O., Okmanis M., Indriksons A., Ruba J., Polmanis K., Freimane L. (2013) Assessment of sanitary conditions in stands of Norway spruce (Picea abies Karst.) damaged by spruce bud scale (Physokermes piceae Schrnk.). iForest. vol. 6, pp. 73 – 78.
13. Rūba J. (2012) *Parastās egles (Picea abies (L.) Karst.) jaunaudžu sanitārais stāvoklis Zemgales, Kurzemes un Vidzemes reģionā* (The Sanitary Conditions of Young Forest Stands of (*Picea abies* (L.) Karst.) in Zemgale, Kurzeme and Vidzeme Reģions). Maģistra darbs. LLU, Jelgava, 61 lpp. (in Latvian).
14. Ruba J., Miezite O., Luguza S., Baltmanis R. (2013a) Abiotic risks of managing young forest stands of Norway Spruce (*Picea abies* (L.) Karst.). Latvia University of Agriculture, Annual 19th International Scientific Conference Proceedings "Research for Rural Development", *2*, pp. 27 – 33.
15. Ruba J., Miezite O., Luguza S. (2014) Impact of Risk Factor Management on the Sanitary Condition of Norway spruce (Picea abies[L.] Karst.) pure stands in Latvia. Journal of Forest Science 60, vol. 5, pp. 181 – 189.
16. Statistical inventory of Latvian forest resources (2010) Latvijas meža resursu statistiskā inventarizācija (Statistical inventory of Latvian forest resources). Available at: http://silava.lv/24/section.aspx/View/119, 29 February 2014. (in Latvian).
17. Statistical inventory of Latvian forest resources (2012) Meža stāvoklis Latvijā 2012. gadā (Latvian forest state in 2012). Available at: http://www.silava.lv/73/section.aspx/301, 29 February 2014. (in Latvian).

18. Tauriņš E. (1982) *Latvijas zīdītājdzīvnieki* (Latvian Mammals). Rīga: Zvaigzne, 255 lpp. (in Latvian).
19. State Forest Service (2007) Meža digitālā karte (Preparation of digital forest map). Available at: karte.vmd.gov.lv:7777/vmdgis/main.jsp, 26 February 2013.
20. State Forest Service (2012a) Meža apsaimniekošana (Forest management). Available at: http://www.vmd.gov.lv/valsts-meza-dienests/statiskas-lapas/-meza-apsaimniekosana-?nid=870#jump, 29 February 2014. (in Latvian).
21. State Forest Service. (2012b) Meža veselības stāvokļa uzraudzība (Forest health monitoring). Available at: http://www.vmd.gov.lv/valsts-meza-dienests/statiskas-lapas/meza-veseliba/meza-veselibas-stavokla uzraudziba?nid=880#jump, 29 February 2014. (in Latvian).
22. Руба Е.О., Миезите О.В., Дрейманис А. (2012) Оценка рисков повреждений копытными при выращивании еловых молодняков в Латвии (Risk Assessment of Browsing Damages in Spruce Young Stands in Latvia). *Экология родного края: проблемы и пути решения*. Киров, 121 – 124. с. (in Russian).

RESEARCH ON BIRCH SPECIES IN LITHUANIA: A REVIEW STUDY

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Abstract
This brief review of the recent birch studies is focused on different aspects, such as species distribution, growing conditions, species identification, changes due to environmental factors. All mentioned investigations were carried out in Lithuania. This analytical study summarises the results and increases knowledge dissemination to the international audience. When reviewed and summarized considerable part of relevant literature sources, we realised new problems and challenges; for example, aiming to clarify the peculiarities of the growth and crown condition of the dominant birch species (*Betula pendula* Roth. and *B. pubescen*s Ehrh.) under the changing climate and anthropogenic pollution.
Key words: *Betulae* sp., Lithuania, habitat, identification, crown condition, phenology.

Introduction

Some decades ago the birches were called 'forest weeds' or just species of low value in Lithuania. Possibly, it was due to several reasons. The priority was given to the dominated coniferous species – Scots pine and Norway spruce. Also, the demand of birch wood for industrial purposes was very low at that time. These reasons were enough serious and forest managers reduced the areas of birches to the minimum.

According to Matyssek (2001), the birch is an economically important tree species in the whole Northern Hemisphere. However, the economic value of downy birch is much lower in comparison with coniferous or silver birch (Hynynen et al., 2010; Niemistö, 2013). The situation in Lithuania also changed a lot in the recent years. The wood industry found birch wood as relatively perspective and valuable for furniture production. Forest research based on various aspects of climate change realized this species as more resistant to diseases and pests outbreaks if compared to Norway spruce, Common oak or European ash. Among other advantages, it is necessary to mention that birches are very important for the biodiversity, i.e. a large number of species feed on or live together with birch, including fungi, herbivores, saproxylic insects, etc. (Hynynen et al., 2010).

There are some review studies based on birch species in Europe (for example, Hynynen et al., 2010), in a narrow aspect some reviewed materials can also be found in Lithuania (Baliuckienė and Baliuckas, 2005). However, the problem is that the results of Lithuanian studies are mostly published in Lithuanian language, and this limits the knowledge dissemination to international audience.

The purpose of this paper was to review recent research on identification, distribution, condition and response to environmental stresses of dominant birch species in Lithuania, aiming to highlight knowledge gap in this field.

Results and Discussion

History of birch species in Lithuania

Depending on the ongoing post-glacial climatic fluctuations, Lithuanian forest composition over the last 10 thousand years often changed. The composition of vegetation in six different regions of Lithuania was restored by pollen data of lakes and mire deposits. Also, the development of climate and soils during the Late Glacial and Holocene period was discussed by Kabailienė (2006). The author stated that historically birch together with pine forests became dominant in the Alleröd (10900–11900 BP) stage when a considerable warming took place in Lithuania. Later, during the Younger Dryas (10900–11900 BP) the dwarf birches (*Betula nana* and *B. humilis*) dominated. Analysing the changes in vegetation composition at different stages during the Holocene, it was found out that in Preboreal and Early Boreal (8100–10000 BP) birches comprised 50 – 80% of all forests in Lithuania. The next increase in birch species was noticed in the Early Subatlantic stage (1000–2500 BP) when *Betula* and *Alnus* were spread in the whole Lithuania. Also, *Pinus* was growing. Similarly, the pollen of *Betula* and *Pinus* prevailed among trees during the last 1000 years (the Late Subatlantic).

Analysis of more recent period, i.e. during the recent 90-year period, showed that the areas of the most dominated tree species had changed in Lithuania. Total area of birch-dominated stands came closer to the total areas of other dominated species (Table 1).

Comparing the data of the most dominant deciduous trees, the birch area showed the largest increase from 1922 (R^2=0.85). The area of birch showed a consistent upward trend, and this allows us to predict the further increase in the next decades.

Growing conditions

The most widely distributed deciduous tree species in Lithuania are birches *Betula pendula* Roth. and *B. pubescen*s Ehrh. (dominant in about

Table 1

Total areas of the most dominated tree species in Lithuania in 1922 – 2012 (%)

	Assessment years									
	1922*	**1931**	**1941**	**1953**	**1961**	**1972**	**1983**	**1988**	**2002**	**2012**
Scots pine	37.0	36.3	41.5	42.9	45.9	45.2	43.3	43.0	36.7	35.1
Norway spruce	35.4	36.5	30.3	27.3	20.2	17.9	20.7	23.0	23.1	20.8
Birch sp.	12.2	12.1	11.2	13.5	16.6	19.6	21.3	20.1	19.9	22.3

* Some data could be missing

23% of forest stands). Four species of birches occur naturally in Lithuania but only two of them, silver birch (*B. pendula*) and downy birch (*B. pubescens*), form productive forest stands or forest communities (Patalauskaitė, 1997) and could be valued as commercially important species. These birch species grow up to 25-30 meters height with one or many stems. Birches are light-demanding pioneer species that rapidly occupy open areas, creating favourable conditions for the immigration of other trees. Both, silver and downy birch species are considered as pioneer tree species. However, downy birch (*B. pubescens*) is considered to be even more adaptive under the unfavourable environmental conditions. In Lithuanian studies, it was observed that downy birch predominates in primary birch forest communities, while silver birch forms does it in secondary communities (Patalauskaitė, 1997).

In Lithuania, birches more often grow in mixed stands than in pure stands. Silver birches mainly occupy the central and north-eastern part of Lithuania. Otherwise, these species have a wide natural distribution area on the whole Eurasian continent (Hynynen et al., 2010). Downy birches are found in the whole territory of the country, especially in more wet sites.

Other two species, *Betula humilis* Scrak and *B. nana* L., are found growing as single trees in Lithuania. The latest species most often grow in wet peat soils, *B. nana* L. needs relatively acid substrate.

According to the Lithuanian recommendations for birch growing (MSTD/AM/LMI, 1999), it is clear that birch species can grow in almost all forest sites. But if they grow in nutrient poor sites, they grow weakly, do not form forest stands (Bareika and Ozolinčius, 2006). For example, downy birches growing in temporarily overmoistured and peatland soils form non-productive stands of bad condition.

In Lithuania, the most characteristic hydrotopes for silver and downy birches are N (normal moisture), L (temporarily overmoisture), U (permanently overmoisture) and P (undrained peatland) according to the Lithuanian classification (Vaičys et al., 2006). The most suitable forest sites for both mentioned birch species are Ld and Lf (eutrophic and very eutrophic soils of temporarily overmoisture), Uc and Ud (mesoeutrophic and eutrophic soils of permanently overmoisture) (Table 2). Silver birch is more common in the sites of normal moisture (N), downy birch - on waterlogged (U) sites. With the stand age, the number of silver birches in the stands on L sites increases, while that of downy birches decreases (Bareika and Ozolinčius, 2009a).

Summarizing the data, it should be noticed that downy birch is less soil demanding and adapted to grow on wet habitats. Despite the fact that the optimal habitats for both species (*B. pendula* and *B. pubescens*) are described as relatively fertile and not overmoistured. They are often found in dry or wet forest sites. Bareika and Ozolinčius (2009a) concluded that the distribution of silver and downy birches in different sites and stand age groups is preconditioned by site hydrological conditions (birches are susceptible to drought conditions), while no significant influence of site trophotope was found.

Birch species identification

In Lithuanian studies it was considered that naturally growing birch species readily cross with each other (Bareika, 2008), but the foreign experience showed that hybrids between silver and downy birch are rare (Jonsell, 2000). Most often silver and downy birches are considered as birch species in practical forestry and forest inventories in Lithuania because these species resemble each other in general appearance. The hybridization of both birch species more often is possible when cold weather prevails in the spring and the phases of trees of late flowering form coincide with the phases of early forms of downy birch (Bareika, 2008).

Following this fact, the identification of most dominated birch species is a very relevant problem. The chemical (sediments) method, based on the reaction of inner bark with 2.4-dinitrophenylhydrasine (according to Lundgren et al., 1995), was first applied for the birch species identification in Lithuania in 2006 (Bareika, 2008). The author has also systematized and analysed the main birch characteristics that are most suitable for species identification. The most important morphological traits identifying silver and

Table 2

Forest sites for birch species (adopted from MSTD/AM/LMI, 1999)

Forest site according to the Lithuanian classification (Vaičys et al., 2006)	***Betula pendula***	***Betula pubescens***
Na (very oligotrophic soils of normal moisture)	+	
Nb (oligotrophic soils of normal moisture)	+	
Lb (oligotrophic soils of temporarily overmoisture)	+	
Ub (oligotrophic soils of permanently overmoisture)		+
Pb (oligotrophic soils of undrained peatland)		+
Nc (mesoeutrophic soils of normal moisture)	+	
Lc (mesoeutrophic soils of temporarily overmoisture)	+	
Nd (eutrophic soils of normal moisture)	+	
Ld (eutrophic soils of temporarily overmoisture)	+	+
Nf (very eutrophic soils of normal moisture)	+	
Lf (very eutrophic soils of temporarily overmoisture)	+	+
Uc (mesoeutrophic soils of permanently overmoisture)	+	+
Ud (eutrophic soils of permanently overmoisture)	+	+
Uf (very eutrophic soils of permanently overmoisture)		+
Pd (eutrophic soils of undrained peatland)		+
Pc (mesoeutrophic soils of undrained peatland)		+

downy birches were stickiness of buds, lift height of outer bark, the form of leaf top, blotchiness and/or pubescens of shoots, pubescens of leaves and petioles, the depth of bark fissures, the form of lamina, distance to the widest section of leaf from the base, expressed in relative length of lamina and leaf base form (Bareika and Ozolinčius, 2006). He found that species identification according to morphological and chemical methods coincided by 96.9%.

Later, when two birch species were identified using the method of morphological traits (Bareika and Ozolinčius, 2006) and chemical method applied (Lundgren et al., 1995; Lithuanian case was presented by Bareika, 2008), additionally, the genetic method (Bareika et al., 2007) was applied for the identification of these species. It was found that the morphological, chemical and genetic methods applied together can be used for the identification of silver and downy birch, but the reliability of all the methods comprised 90.6%.

Response to environmental stresses: biotic, abiotic and anthropogenic factors

Despite the fact, that silver birch is one of the most resistant species to tree diseases and pest infestations, it could be damaged by both biotic and abiotic factors. In Lithuania, the analyses of the most frequent damages of birch species was presented by Araminienė et al. in 2013. The analyses of the condition of *B. pendula* and *B. pubescens* in Lithuania showed that mean defoliation in 1989 – 2011-year period ranged between 16.2 – 23.0% and showed a very slight trend of degradation. Up to 1.3–1.5 times lower defoliation was typical for dominant and co-dominant birch trees (1st and 2nd Kraft classes) if to compare with the subdominant trees (3rd Kraft class).

The biotic and abiotic factors affecting the birches in Lithuania are grouped as follows: abiotic factors 15% - wind damages 41.97%, snow (rime) 10.58%, cold 5.85%, flooding 4.96%, bark stripping 22.75%, drought 13.63% and biotic factors 85% - animal damages 11.88%, insects 63.67%, fungi and diseases 26.52%. The analyses of the data obtained during the 1991-2011-year period showed no clear dynamics of the number of birch trees damaged by abiotic and biotic factors (Araminienė et al., 2013). The significant peaks were registered 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 found 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) had significantly decreased starting from 1991, but no clear changes in mean defoliation were recorded.

The visible injuries of ozone fumigation on birch saplings were studied by Serafinavičiūtė et al. in 2008. They found the increase of visible injuries and decrease of chlorophyll in the foliage of 4 years-old saplings of silver birch (*Betula pendula*) after

one month of ozone fumigation with 80-240 µg m^{-3} concentrations in closed climatic chambers. The dry mass of the foliage of ozone-affected saplings also decreased if compared to the control.

If the anthropogenic activity (forest thinning) we treated as an acting factor, here it would be important to mention the study performed in 10 – 60 year-old stands of various species – ash, aspen, oak, pine, spruce, including birch, in Lithuania (Juodvalkis et al., 2005). It showed that thinning increased the increment of crown projection area of left trees. Therefore, the largest effect was found in the birch stands whose growth increased by 200%. Thinning of low and moderate intensities stimulated the volume increment in younger stands, and for birch it was the age of 10 – 20 years old.

Crown condition

The results given in Fig. 1 showed that the mean defoliation of birches in Lithuania ranged from 16.2 to 23.0%. The studies of birch crown condition were presented by several authors (Juknys and Augustaitis, 1998 a,b; Stakėnas and Ozolinčius, 1998; Stakėnas et al., 2013). The data analyses showed the increased number of damaged birches found in some periods (Stakėnas et al., 2013). For example, in 1993-1995 this value comprised 20.4 – 25.2%, and possibly was caused by strong winter winds in 1993, then followed by pest outbreaks.

During the 2003 – 2004-year period, the higher number of damaged birches (21 – 22.6%) could be caused by birch deceases outbreak. The maximum number of damaged trees was found in 2012, and it amounted to 29.4%. Meanwhile, in 1989 this value was 16.2%, and in different time periods up to 2011 ranged about 17 – 23%. 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 climate change.

Phenology

Phenological studies in five 40-70-year-old birch stands (silver and downy birches) growing on the sites of similar fertility were carried out during 2004 – 2006 (Bareika and Ozolinčius, 2007; Bareika and Ozolinčius, 2009b). The author found out that the cast of silver birch seeds during the studied years started by two weeks earlier than that of downy birch, on 1-5 August and 14-16 August, respectively. Similarly, the most intensive seed cast (about 50% of seeds were dispersed) started on 15-18 August for silver birch and 25 August–1 September for downy birch. Summarizing the data about the duration of seed cast periods of both species, the author stated that the seed cast of downy birch was more intensive, i.e. about 80% of birch seeds fell down in 10 days shorter period than the seeds of silver birch (Bareika and Ozolinčius, 2009b).

The variability of the phenological time series for the 1971 – 2000-year period and the assessment of the climate change impact on phenology in Latvia and Lithuania were performed by scientists from both countries (Kalvane et al., 2009; Romanovskaja et al., 2009). Next to other species, silver birch was also studied. The significant findings from these studies showed that all phenophases of the phenological seasons during the studied period in Lithuania started

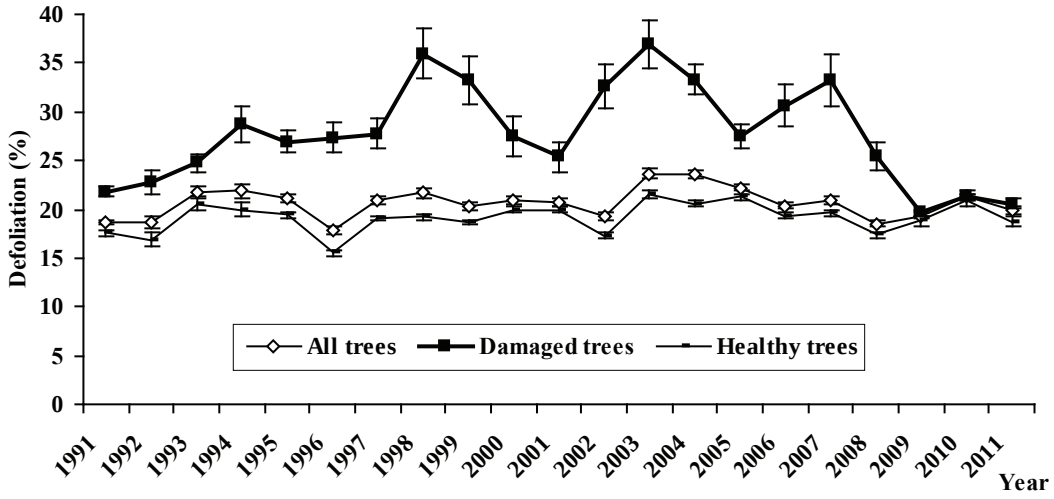

Figure 1. Mean defoliation (%) of all birch trees, damaged and healthy trees in 1989 – 2011 (adopted from Stakėnas et al., 2013).

up to 11 days earlier than in Latvia. However, the duration of the phenological spring season was by 39 days longer than summer season in both countries. The changing climate significantly increased the duration of some phenological seasons, and it was especially clear in the years 1991 – 2000 (Romanovskaja et al., 2009).

Other studies: birch sap, wood, genetic research and pollen

There were several studies based on various aspects of birch species in Lithuania. The chemical composition of birch sap was assessed by Viškelis and Rubinskienė in 2011. It was the first sap quality study in Lithuania. Despite the fact that this natural product has been used from old times, the data emphasized the nutritional and healing value of this product. Among nine macroelements and microelements in fresh birch sap, the main obtained element was potassium, and it comprised over 115 mg kg^{-1} in our climate zone. Following the first results, the birch sap studies were continued. The next study, aiming to evaluate the sap changes during storage and fermentation and to optimize storage parameters, was presented by Viškelis and Rubinskienė in 2012. The study results showed that birch sap for fresh usage can be stored up to two months and the most suitable storage temperature is from 0 °C to +2 °C. The storage of birch sap in lower temperature (up to -1.4 °C) would prolong the duration of its storage.

Some wood properties of birch trees were studied in 2006 (Vobolis and Zavackaitė, 2006). This study was based on the resonance vibrations of a beam type body and aimed to realize the distribution of the dynamic modulus of elasticity and coefficient of damping values in the birch log. Among other specific parameters, the authors found that the elastic properties of birch wood were exchanged by damping properties. Silver birch populations for wood hardness were studied by Baliuckienė and Baliuckas in 2006. The specific goals of this study were to estimate the genotypic variation in wood hardness and growth, further to evaluate the possibilities of inclusion some new trait into the breeding program.

Generally, genetic and breeding research of silver birch was quite episodic up to 2005 in Lithuania. Baliuckienė and Baliuckas in 2005 overviewed the experience of the European studies of the natural regeneration of *Betula pendula*. The authors discussed various aspects of this species, i.e. self-fertilisation, crossability and factors influencing genetic diversity. Also, they gave a review on wood properties and morphological traits inheritance.

Genetic variation and plasticity of silver birch (*B. pendula*) populations were further studied by Baliuckienė et al. (2007). The authors concluded that additive genetic variation found within studied birch populations presumed that species had potential to adapt genetically by natural or artificial selection to climate change.

Summarising the studies performed by Veriankaitė et al. (2010 a, b), we can state that *Betula* genus produce the highest daily pollen concentrations (4 680 grains m^{-3}) during the pollen season in Lithuania. The same authors analysed the climate warming effects on the start of the flowering of some species. The changes were found for the species that begin flowering early in spring, including *B. pendula*. Following the climate change B1 scenario, the flowering start of *B. pendula* is expected to become 5-8 days earlier in Lithuania in the 21st century. According to A2 scenario, the most evident changes could occur closer to the Baltic Sea and in the southern part of Lithuania (more than 33 days), while the least changes – in western part of Lithuania (about 23 days).

Conclusions

1. In the recent decades the area of birch increased and occupied about 22% of the forest area in 2012. Mean defoliation of birches is about 23%.
2. Silver birch is more common on the sites of normal moisture and occupies the central and north-eastern part of Lithuania; downy birches are found on waterlogged sites in the whole territory of the country.
3. The abiotic factors affecting the birches in Lithuania comprise 15%, from which about 42% trees are damaged by wind, 11% by snow, 6% by cold, 5% by flooding, 23% by bark stripping and 14% by drought. The main biotic factors (85%) are animal damages (12%), insects (64%), fungi and diseases (27%).
4. The future birch studies could be orientated to clarify the peculiarities of the growth and crown condition of the dominant birch species (*Betula pendula* Roth. and *B. pubescen*s Ehrh.) under the changing climate (elevated temperature and CO_2) and anthropogenic activities (forest management techniques).

References

1. Araminienė V., Varnagirytė-Kabašinskienė I., Stakėnas V. (2013) The influence of abiotic and biotic factors on the condition of birch species in Lithuania. *The 6th International Scientific conference 'Rural Development 2013'*, Kaunas, Lithuania, pp. 182 – 186.

2. Baliuckienė A., Baliuckas V. (2005) Karpotojo beržo (*Betula pendula* L.) bioekologinės ir genetinės savybės (Silver birch (*Betula pendula* L.) bio-ecological and genetic properties). *Miškininkystė*, 1 (57), pp. 62 – 69. (in Lithuanian).
3. Baliuckienė A., Baliuckas V. (2006) Genetic Variability of Silver Birch (*Betula pendula* L.) Wood Hardness in Progeny Testing at Juvenile Age. *Baltic Forestry*, 12 (2), pp. 134 – 140.
4. Baliuckienė A., Baliuckas V., Pliūra A. (2007) Karpotojo beržo (*Betula pendula* Roth.) populiacijų genetinė įvairovė ir fenotipinis plastiškumas (Genetic variation and plasticity of silver birch (*Betula pendula* Roth.) populations). *Miškininkystė*, 2 (62), pp. 16 – 26. (in Lithuanian).
5. Bareika V. (2008) Karpotasis (*Betula pendula* Roth.) ir plaukuotasis (*Betula pubescens* Ehrh.) beržai Lietuvoje: fenotipiniai skirtumai ir ekologinis paplitimas (Silver birch (*Betula pendula* Roth.) and Downy birch (*Betula pubescens* Ehrh.) in Lithuania: phenotypical differences and ecological distribution). Doctoral Dissertation, Vytautas Magnus University, Kaunas, Lithuania, pp. 112.
6. Bareika V., Ozolinčius R. (2006) Karpotojo (*Betula pendula* Roth.) ir plaukuotojo (*B. pubescens* Ehrh.) beržų identifikavimas: svarbiausi morfologiniai požymiai (Species identification: the most important morphological indices for silver (*Betula pendula* Roth.) and downy birch (*B. pubescens* Ehrh.)). *Miškininkystė*, 1 (59), pp. 19 – 34. (in Lithuanian).
7. Bareika V., Ozolinčius R. (2007) Karpotojo (*Betula pendula*) ir plaukuotojo (*Betula pubescens*) beržų fenologija Lietuvoje (Phenology of silver (*Betula pendula*) and downy birches (*B. pubescens*) in Lithuania). *Botanica Lithuanica*, 9, pp. 25 – 42. (in Lithuanian).
8. Bareika V., Ozolinčius R. (2009a) Karpotojo (*Betula pendula* Roth.) ir plaukuotojo (*B. pubescens* Ehrh.) beržų paplitimas skirtingo drėgnumo augavietėse (Distribution of silver (*Betula pendula* Roth.) and downy birch (*B. pubescens* Ehrh.) on forest sites of different humidity). *Miškininkystė*, 1 (65), pp. 16 – 23. (in Lithuanian).
9. Bareika V., Ozolinčius R. (2009b) Karpotojo (*Betula pendula* Roth.) ir plaukuotojo (*Betula pubescens* Ehrh.) beržų derėjimo ir sėklų byrėjimo fenologijos ypatumai (Phenological peculiarities of seed bearing and seed cast of silver (*Betula pendula* Roth.) and downy (*Betula pubescens* Ehrh.) birch). *Miškininkystė*, 2 (66), pp. 52 – 65. (in Lithuanian).
10. Bareika V., Ozolinčius R., Verbylaitė R. (2007) Karpotojo (*Betula pendula* Roth.) ir plaukuotojo (*Betula pubescens* Ehrh.) beržų fenotipiniai skirtumai ir APPD lokusų polimorfizmas (Phenotype differences and polymorphism of RAPD locus of Silver (*Betula pendula* Roth.) and Downy (*Betula pubescens* Ehrh.) birches). *Miškininkystė*, 2(62), pp. 27 – 42. (in Lithuanian).
11. Hynynen J., Niemistö P., Viherä-aarnio A., Brunner A., Hein S., Velling P. (2010) Silviculture of birch (*Betula pendula* Roth and *Betula pubescens* Ehrh.) in Northern Europe. *Forestry*, 83(1), pp. 103 – 119.
12. Jonsell B. (ed). (2000) Flora Nordica. Volume 1. Lycopodiaceae to Polygonaceae. The Bergius Foundation, the Royal Swedish Academy of Sciences, Stockholm, Sweden, 368. p.
13. Juknys R., Augustaitis A. (1998a) Forest Health Monitoring Indicators and Their Interpretability: A Lithuanian Case Study. USDA Forest Service General Technical Reports PSW-GTR, 166, pp. 313 – 320.
14. Juknys R., Augustaitis A. (1998b) Indicators of crown and their application in forest health monitoring. *Baltic Forestry*, 2, pp. 51 – 58.
15. Juodvalkis A., Kairiukstis L., Vasiliauskas R. (2005) Effects of thinning on growth of six tree species in north-temperate forests of Lithuania. *European Journal of Forest Research*, 124(3), pp. 187 – 192.
16. Kabailienė M. (2006) Main stages of natural environmental changes in Lithuania during the Late Glacial and Holocene. *Geologija*, 55, pp. 37 – 48.
17. Kalvane G., Romanovskaja D., Briede A., Bakšienė E. (2009) Influence of climate change on phenological phases in Latvia and Lithuania. *Climate Research*, 39, pp. 209 – 219.
18. Lundgren L.N., Pan H., Theander O., Eriksson H., Johansson U., Svenningsson M. (1995) Development of a new chemical method for distinguishing between *Betula pendula* and *Betula pubescens* in Sweden. *Canadian Journal of Forest Research*, 25, pp. 1097 – 1102.
19. Matyssek R. (2001) How sensitive is birch to ozone? Responses in structure and function. *Journal of Scientific Computing*, 47, pp. 8 – 20.
20. MSTD/AM/LMI (1999) Beržų auginimas. Kompleksinės rekomendacijos (Birch cultivation. Complex recommendations). Forest Research Institute, Girionys, Kaunas, 27 p. (in Lithuanian).
21. Niemistö P. (2013) Effect of growing density on biomass and stem volume growth of downy birch stands on peatland in Western and Northern Finland. *Silva Fennica*, 47(4), pp. 1 – 24.
22. Patalauskaitė D. (1997) The Role of *Betula pendula* and *B. pubescens* in Lithuanian Forest Communities. Botanica Lituanica, 1, pp. 139 – 140.

23. Romanovskaja D., Kalvane G., Briede A., Bakšienė E. (2009) Klimato šiltėjimo įtaka fenologinių sezonų trukmės pokyčiams Lietuvoje ir Latvijoje (Influence of climate warming on the changes of the length of phenological seasons in Lithuania and Latvia). *Žemdirbystė*, 96(4), pp. 218 – 231. (in Lithuanian).
24. Serafinavičiūtė B., Stakėnas V., Sakalauskaitė J. (2008) Effects of ozone on photosynthetic apparatus of silver birch (*Betula pendula* Roth.) saplings. *Vagos*, 81, pp. 54 – 59.
25. Stakėnas V., Beniušis R., Varnagirytė-Kabašinskienė I., Araminienė V., Žemaitis P., Čapkauskas G. (2013) Medžių būklės kaita Lietuvoje 1989 – 2012 metais (The changes of tree condition in Lithuania in 1989 – 2012). *Miškininkystė*. 1(73), pp. 7 – 18. (in Lithuanian).
26. Stakėnas V., Ozolinčius R. (1998) Medžių lajų defoliacija Lietuvoje ir jos dinamika (Tree crown defoliation and its dynamics in Lithuania). *Miškininkystė*, 1(41), pp. 81 – 92. (in Lithuanian).
27. Vaičys M., Karazija S., Kuliešis A., Rutkauskas A. (2006) Miškų augavietės. Miško augaviečių tipai (Forest sites). Lututė, Kaunas, Lithuania, 95. p. (in Lithuanian).
28. Veriankaitė L., Šaulienė I., Bukantis A. (2010a) Analysis of changes in flowering phases and airborne pollen dispersion of the genus *Betula* (birch). *Journal of Environmental Engineering and Landscape Management*, 18(2), pp. 137 – 144.
29. Veriankaitė L., Siljamo P., Sofiev M., Šaulienė I., Kukkonen J. (2010b) Modelling analysis of source regions of long-range transported birch pollen that influences allergenic seasons in Lithuania. *Aerobiologia*, 26 (1), pp. 47 – 62.
30. Viškelis P., Rubinskienė M. (2011) Beržų sulos cheminė sudėtis (Chemical composition of birch sap). *Sodininkystė ir daržininkystė*, 30(1), pp. 75 – 81. (in Lithuanian).
31. Viškelis P., Rubinskienė M. (2012) Changes of birch sap quality indices during storage. *Sodininkystė ir daržininkystė*, 31(1–2), pp. 63 – 73.
32. VMT/MSAS. (2013) Lietuvos valstybinių miškų 2012 m. sanitarinės būklės apžvalga (Overview of Lithuanian State Forests condition in 2012). Valstybinė miškų tarnyba Miško sanitarinės apsaugos skyrius. Kaunas, Lithuania, 77. p. (in Lithuanian).
33. Vobolis J., Zavackaitė L. (2006) Studies on Birch Wood Viscoelastic Properties. *Materials Science (Medžiagotyra)*, 12(1), pp. 31 – 36.

CLIMATE SUITABILITY EFFECT ON TREE GROWTH AND SURVIVAL FOR SCOTS PINE PROVENANCES IN LATVIA

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Abstract
Climate in Latvia has been changing in last decades, and it is predicted to continue changing; therefore, it is important for forestry sector to understand how these climatic changes might affect tree growth and survival. In order to assess climate suitability effect on Scots pine (*Pinus sylvestris* L.) provenances in Latvia, height and survival data from a Scots pine provenance trial located in three geographically distant places in Latvia were analysed together with several climatic indices. Provenances in the corresponding trial originated from Latvia, Poland, Germany, Belarus, Russia and Ukraine. Thirty year average climate data values from 1961 – 1990 for the 64 origins of provenances were acquired from the WorldClim project. Correlation analysis between provenance average values for height and survival and climate index values for the origins of the provenances confirm that there is a relation between these amounts, and the relation differs between the three site locations, indicating that suitability of climate is an important factor affecting the results of provenance trials. Cluster analysis confirmed that provenances from distant origins might have a very similar growth and survival rates; therefore, geographical location of the provenance origins cannot be considered as the only influential factor on these rates and the results from provenance trials have to be analysed together with climate data in order to make conclusions about the suitability of the provenances.
Key words: provenance, suitability, spatial analysis, Scots pine, climate.

Introduction

Forestry sector plays an important role in Latvia's economy, ensuring employment for 8% of the workforce and creating from 18% to 37% of the annual export value in the last decade; therefore, steady supply of high quality round wood for processing is a long term important objective of forest policy. However, rapid climatic changes are occurring and affecting the forest, as demonstrated by numerous observations e.g. of tree ring chronologies (D'Arrigo et al., 2008) and phenological indicators (as compiled in Pan European Phenology database – www.pep725.eu); the rate of change is predicted to increase in future (Solomon et al., 2007). Therefore, intensive work has been carried out to better understand the changes at local and a landscape scale in different countries including Latvia (Jansons, 2010). Results have been linked to characteristics of individual tree growth, stand development dynamics, from which country-wide or global predictions of impacts of climatic change on forest ecosystems are created (Read et al., 2009; Seppälä et al., 2009; Lindner et al., 2010) and coupled with the recommendations for forest management measures to boost adaptive capacity and reduce the possible harmful effects to forest stands (Lindner et al., 2008).

According to data from the National Forest Inventory, the forest in Latvia is dominated by Scots pine (*Pinus sylvestris* L.) (29%), birch — predominantly silver birch (*Betula pendula* Roth) — (28%) and Norway spruce (*Picea abies* (L.) Karst.) (17%). Each of these species has a wide geographical distribution; therefore, different genotypes grow in very different climatic conditions. Numerous provenance trials, including the International Union of Forest Research Organizations (IUFRO) series and Pravdins series (in the former Soviet Union) have been established (Giertych, 1979; Shutyaev and Giertych, 2000). The results clearly demonstrate provenance differences in survival and/or growth. Some provenances tried in Latvia (e.g. Scots pine from the Angasyak region close to the Ural Mountains) are very poor even though performance is good in the native region and despite the fact that transfer is good within the boundaries of the species natural distribution area. Notable variation among provenances in traits important for adaptation like bud burst, growth cessation, and frost hardiness, also occurs (Hurme, 2000). Results suggest that even for species with relatively high phenotypic plasticity as Scots pine, Norway spruce and Silver birch (Koskela et al., 2007) natural selection has played an important role in adaptation to local environmental conditions. Therefore, even if the climate change predicted in the future is within the range of climatic conditions that occurred in Latvia since the glacial period, the rate of change might cause considerable mortality due to natural selection in native populations of these species. A combination of different adaptation mechanisms, like intensive gene flow also from far distances via wind pollination and seed dispersal, may ensure the survival of species, but is unlikely to meet the human interest in maintaining productive forest stands in successive generations. Tree quality, including traits like stem straightness, thin branches,

wide branch angle etc., is important for timber processing and is incorporated in the selection index in most of the breeding programs in Northern European countries. However, natural selection might not affect these traits to large extent. Therefore, to ensure both productivity and good timber quality of forest stands in Latvia, through a rapidly changing climate, active measures need to be taken. Provenances of the main species suitable for predicted climatic conditions need to be identified and included in breeding programs to produce material for forest regeneration.

Questions of possible impacts of climatic change on forest ecosystems and the need for adaptation has formed an important research agenda during the last decade in most of European countries. Special emphasis has been in the regions where the impact is already affecting practical forestry (like droughts and forest fires in Mediterranean region). As the future climate projections for Latvia suggest, survival and productivity of stands of our main tree species might be severely affected. Therefore, it might be an advantage to use provenances from Poland and/or Germany or other regions that could be better suited to predicted climatic conditions. However, detailed analysis on complex effects of environmental factors like soil characteristics and wind regime needs to be considered along with a complex analysis of climatic conditions and their effect on different traits of tree quality and yield before any recommendations could be drawn. So far in Latvia the research field of forest adaptation has focused on the impacts of wind, drought (and related increased fires risks) as well as pests and diseases. Advanced research in physiological reaction to particular meteorological conditions (e.g. increase in soil temperature) has also been carried out. Genetic factors, with few exceptions, were included into adaptation research only within the last few years. Such studies have been dedicated mostly to resistance against pests and pathogens and to gene migration. Therefore, the aim of this paper is to provide qualitatively new, broader scale information on the suitability of provenances to climatic conditions in Latvia that could trigger further national research activities dealing with more detailed analysis of the suggested provenances and role of genetic factors to ensure forest adaptation and adaptability in general.

Materials and Methods

Climate data were analysed together with Scots pine provenance trial data. The trial was established in 1975 with one year old seedlings in three geographically distant places in Latvia with similar ecological conditions (Liepaja, Zvirgzde and Kalsnava). Seed material from 64 different origins was planted, including 27 provenances from Germany, 8 from Poland, 3 from Russia, 1 from Belarus, 1 from Ukraine and 18 provenances and 6 seed orchards from Latvia. The same material was used in all three locations. Trial design — two blocks with 6 replications, 7 by 5 plants in a parcel with the initial spacing 2 by 1 m. Height data at the age of 11 and 21 as well as survival rate at the age of 10 and 21 (before the first thinning) at provenance mean level were used in the analysis, no thinning had been carried out prior to the measurements. The climate data were extracted for specific coordinates that were based on provenance trial data about the origins of the provenances and the locations of trial sites.

The climate data have been taken from the WorldClim project (Hijmans et al., 2005). The data represents monthly average values for the 1960 – 1990 period, that have been interpolated to get data layers for 30 arc-second resolution grid (1 km^2 resolution). Precipitation and temperature values have been taken and other indices have been derived based on those values, such as moisture deficit, accumulated temperature sum, and Conrad's continentality index (Conrad, 1946). The moisture deficit is the accumulated difference between potential evapotranspiration (estimated by Hargreaves formula, Hargreaves and Samani, 1982) and precipitation from the months when precipitation level is lower than potential evapotranspiration, which is mainly during the growing season. It represents the possibility of drought occurrence during the vegetation period. Accumulated temperature sum is the yearly average sum of degrees above 5 °C for the days when mean daily temperature is above 5 °C. In this case only mean monthly temperatures were available, so accumulated temperature sum was estimated by taking the sum of degrees above 5 °C and multiplying it with the count of days in the month. A coefficient of continentality was formulated by V. Conrad in 1946 (1), and it represents the influence of landmass (the opposite of oceanicity), which is calculated as the difference between mean temperatures of the warmest and coldest months of the years, divided by the sine of the latitude, as the temperature difference increases with the latitude:

$$k = \frac{1.7A}{\sin(\varphi + 10°)} - 14 \quad (1)$$

where k — continentality, A — difference between the mean temperature (°C) of the warmest and coldest months and φ is the latitude of the place in question.

Correlation analysis was used to evaluate relations between the provenance mean data at each location and the average climate, latitude, longitude and altitude data for the origins of the provenances. Cluster analysis with k means algorithm was used to group provenances based on each trait at each location. The number of clusters in each case was determined graphically by the bend in a within groups sum of

squares by the number of clusters plot. Afterwards the average climate data for each cluster and the difference from the site location's climate data was calculated to evaluate the climatic suitability effect on height and survival. Spatial analysis was done to map the results of the cluster analysis and to visually assess the geographical influence on traits. Mathematical analysis was carried out using statistical software R 3.0.2, while spatial analysis was done using QGIS 2.2.0-Valmiera.

Results and Discussion

As the three site locations have slightly different climatic conditions, it was expected that the results would differ among the sites. Kalsnava has the most continental climate with mean annual temperature 5.4 °C and 673 mm of precipitation per year, from which larger part is concentrated in the warmest months of the year, while Liepaja is closer to the sea and has the least continental climate from the three sites with mean annual temperature 6.8 °C and 692 mm of precipitation, which is distributed more evenly through the year. Zvirgzde is located approximately in the middle between Kalsnava and Liepaja, and also climatically is somewhere in between with mean annual temperature 6.2 °C and 637 mm of precipitation per year.

Several authors suggest that latitude is one of the most influential factors for growth traits (Andrzejewski et al., 1998; Kohlstock and Schneck, 1998; Matras, 1998), which seems to be true in most cases in our analysis (Table 1), especially for the results from Kalsnava, but for Liepaja and Zvirgzde there is almost no correlation between height and latitude, except for the height at the year 21 in Zvirgzde, which suggests that other factors, such as climate both in origin's and site locations, could have a stronger influence on growth traits than latitude. This statement is also validated by the different correlations of traits with continentality for different locations. For example, there is a statistically significant ($p<0.01$) positive correlation between survival and continentality in Kalsnava, while in Liepaja this correlation is very weak, but it is negative, which means that provenances from origins with more continental climate have a greater probability of survival if they are planted in a site with more continental climate. In Liepaja, there is a significant negative correlation for height with the coefficient of continentality, which becomes more pronounced at the age 21 than at the age 11, while in Kalsnava the correlation is positive, but very weak. It means that provenances in Liepaja have similar probability of survival regardless of the suitability of continentality, but less suitable provenances will grow more slowly; on the other hand, in Kalsnava more suitable provenances have greater survival probability and if they managed to survive, they showed similar height growth rates as other provenances.

Accumulated temperature and moisture deficit showed very similar effect on both traits at all locations and ages. Provenances in Kalsnava from origins with high moisture deficit (or accumulated temperature) had a very low survival rate, which could be due to frost resistance, because high moisture deficit an accumulated temperature is typical for places with warmer climate than in Kalsnava. This relation becomes more pronounced in the western part of Latvia (in other words – in sites with less continental climate), which also approves the previous statement as the winters are much milder in the western part of Latvia with rarer spring and autumn frosts. The same geographical trend is applicable also for the height; however, correlation is weaker in this case. Precipitation was the only variable that had a statistically significant correlation in all the cases, showing the trend that provenances from origins with higher annual precipitation level have both higher survival and height. Mean annual temperature was another variable that confirmed the importance of climatic suitability on height growth and survival rate, as the geographic trend was valid in all the cases, confirming that provenances from warmer places have worse results in a colder site and also the other way round. As Ā. Jansons and I. Baumanis (2008) point out, other traits, such as stem straightness and branch thickness, also have to be assessed, as provenances from abroad might succeed in one trait while failing in other, which is also proven by the fact that some provenances had a good height rate despite having a very low survival rate.

Correlation analysis showed no relation with altitude; therefore, altitude was excluded from further analysis. It could be mainly due to the small range of altitudes at provenances origins (15 – 201 m above sea-level) that is basically the same altitude level as in Latvia.

Cluster analysis based on provenance average values for traits was done in order to see if the provenances would group mainly according to their geographic origins. As it was expected, the influence of location on the clusters was apparent, but also provenances from geographically distant origins had very similar patterns both in height growth and survival rates. In some cases provenances from Latvia grouped together with provenances from Germany, mainly when height data were used for clustering, but also for survival in Liepaja and Zvirgzde. For example, when clustering by survival at the age 21 in Liepaja (which is located close to the Baltic sea), provenances from Latvia and Germany with origins close to the sea grouped together and showed the second best survival rate. On the other hand, when clustering by height at

Table 1

Pearson's correlation coefficients between traits and climatic and geographical indices for different locations and ages

Location	Age	Trait	Altitude	Continentality	Accumulated temperature	Moisture deficit	Latitude	Longitude	Precipitation	Temperature
Kalsnava	10	survival	0.02	0.42**	-0.72**	-0.7**	0.81**	0.02	0.62**	-0.53**
Liepaja	10	survival	0.05	-0.04	-0.29*	-0.29*	0.45**	-0.52**	0.54**	0.10
Zvirgzde	10	survival	0.03	0.14	-0.38**	-0.42**	0.53**	-0.37**	0.53**	-0.07
Kalsnava	21	survival	0.02	0.37**	-0.69**	-0.68**	0.76**	-0.09	0.64**	-0.44**
Liepaja	21	survival	0.01	-0.08	-0.27*	-0.29*	0.44**	-0.53**	0.53**	0.11
Zvirgzde	21	survival	0.04	0.11	-0.20	-0.24	0.46**	-0.39**	0.43**	0.05
Kalsnava	11	height	-0.09	0.16	-0.41**	-0.38**	0.52**	-0.32*	0.53**	-0.13
Liepaja	11	height	0.08	-0.29*	-0.01	0.03	0.12	-0.7**	0.42**	0.34**
Zvirgzde	11	height	0.01	-0.17	0.06	0.09	0.14	-0.53**	0.28*	0.29*
Kalsnava	21	height	-0.07	0.04	-0.39**	-0.34**	0.47**	-0.46**	0.56**	-0.01
Liepaja	21	height	0.05	-0.41**	0.13	0.13	0.07	-0.78**	0.44**	0.45**
Zvirgzde	21	height	-0.02	-0.15	-0.02	-0.02	0.28*	-0.54**	0.39**	0.23

* – significant at 0.05 level; ** – significant at 0.01 level

the age 21 in Kalsnava, provenance groups with the best height data consisted of provenances all across Latvia, Germany and Poland, but in the same time the second worst height data were for a set of German provenances originating from very close locations to those of the best height data, showing no clear trend. The only clear trend was that provenances from Ukraine and Russia had the lowest height, possibly indicating that these provenances originated from places with more unsuitable climate for growing in Kalsnava. Of course, the small number of provenances from that region limits our possibilities to make accurate conclusions.

In order to explore the suitability of climate indices, values of the indices were expressed as a percentage of the respective climate index value at each of three site locations. Then these values were analysed in accordance with the cluster average trait values. The results showed a tendency that provenance groups (clusters) with the best growth and survival rates were from origins with very similar climatic conditions to that of the site location, while the worst trait rates were observed for provenance groups with the largest deviations in climatic conditions (Figure 1). It means that climatic conditions have a complex influence on the growth and survival rates and analysis of singular climatic variables could lead to inaccurate conclusions. This observation suggests that it might be possible to select provenances from distant regions, but with similar climate conditions as in the planned forest regeneration location, which would result in good height and survival rates. Also, it would be possible to select seed material that is more suitable for the projected future climatic conditions, taking into consideration more influential factors and resulting in a lower risk of uncertainty in forest adaptation.

Conclusions

It is clear that suitability of climate has a direct effect on both height and survival of Scots pine;

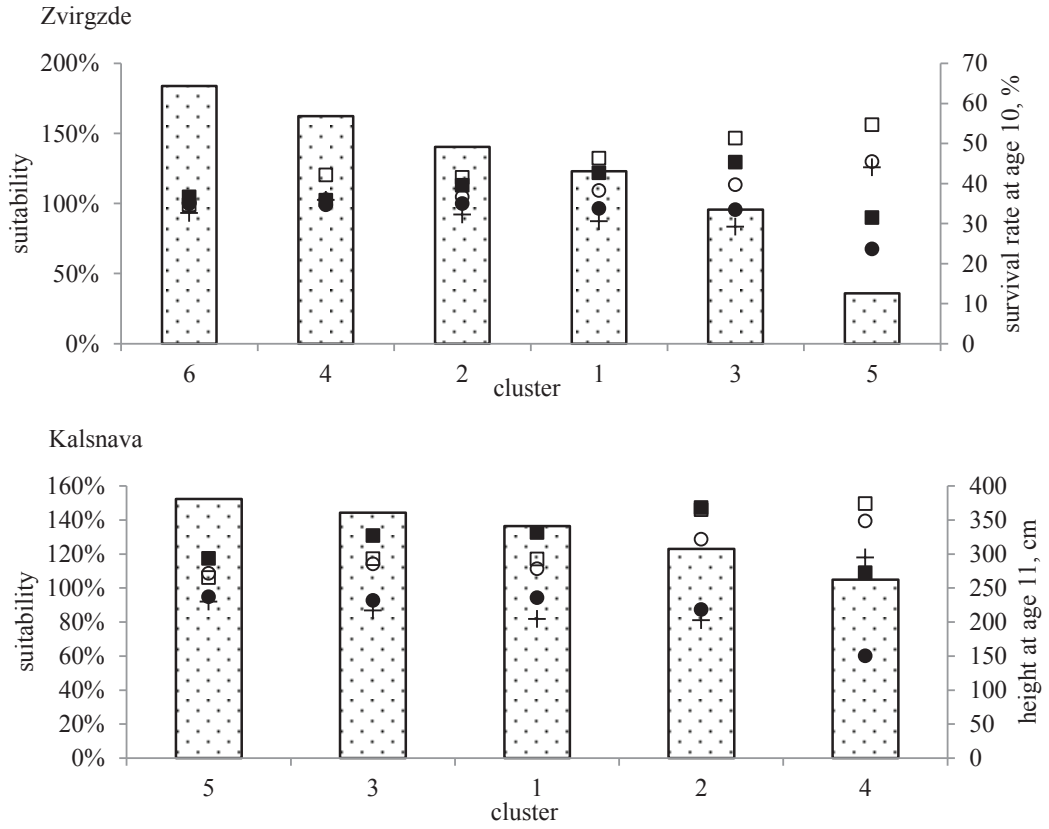

Figure 1. Differences between average climate indices for origins and trial locations in relation to provenance groups clustered by similar trait patterns: left axis: □ moisture deficit; ■ temperature; ● precipitation; ○ accumulated temperature sum; + continentality; right axis: Zvirgzde – survival; Kalsnava – height.

therefore, results from provenance trials need to be analysed along with the climate data from the origins of provenances. That way a better understanding about the results can be acquired than by using just the information about latitude and longitude of the origins. As it can be seen from the results, the best height and survival rates were for provenance groups that had very similar climatic conditions as in the respective site location, but additional climate and soil data should be incorporated in further research in order to obtain more precise results.

In order to compare differences in climatic conditions for specific periods of time, more specific climate data from stations close to the origins of the provenances is needed, which would be very useful for assessing the effect of climate change on Scots pine.

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References

1. Andrzejewski K., Kowalkowski W., Rzeznik Z. (1994) Variability of growth and qualitative features of 10-year old Scots pine (*Pinus sylvestris* L.) of 20 European provenances. In: Scots pine breeding and genetics. *Proceedings of the IUFRO S.02.18 symposium*, 1994, Lithuania, Kaunas, pp. 24 – 28.
2. Conrad V. (1946) Methods in Climatology. Harvard University Press, pp. 296 – 300.
3. D'Arrigo R., Wilson R., Lipert B., Cherubini P. (2008) On the 'Divergence Problem' in Northern Forests: A review of the tree-ring evidence and possible causes. *Global and Planetary Change*, 60, pp. 289 – 305.

4. Giertych M. (1979) Summary of results on Scots pine (*Pinus sylvestris* L.) height growth in IUFRO provenance experiments. *Silvae Genetica*, 28 (4), pp. 136 – 152.
5. Hargreaves G.H., Samani Z.A. (1982) Estimating potential evapotranspiration. *Journal of the Irrigation and Drainage Division*, 108(3), pp. 225 – 230.
6. Hijmans R.J., Cameron S.E., Parra J.L., Jones P.G., Jarvis A. (2005) Very high resolution interpolated climate surfaces for global land areas. *International Journal of Climatology*, 25(15), pp. 1965 – 1978. Available at: http://www.worldclim.org/tiles.php?Zone=16/, 10 March 2014.
7. Hurme P. (2000) Genetic Basis of Adaptation: Bud Set Date and Frost Hardiness Variation in Scots Pine: doctoral thesis. Department of Biology, OULU, Finland, 33 p.
8. Jansons Ā., Baumanis I. (2008) Ievesto parastās priedes (*Pinus sylvestris* L.) provenienču augšana un kvalitāte Latvijā (Growth and Quality of Transferred Scots Pine (*Pinus sylvestris* L.) Provenances in Latvia). *LLU Raksti*, 20 (315), 22 – 31. lpp. (in Latvian).
9. Jansons A. (2010) Adaptation of forest management to climatic changes: report. LSFRI Silava, Salaspils, Latvia, 133 p.
10. Kohlstock N., Schneck V. (1998) IUFRO provenance trial of Scots pine (*Pinus sylvestris* L.) at Waldsieversdorf 1982-1994. In: Scots pine breeding and genetics. *Proceedings of the IUFRO S.02.18 symposium*, 1994, Lithuania, Kaunas, pp. 29 – 36.
11. Koskela J., Buck A., Teissier E. (2007) *Climate Change and Forest Genetic Diversity: Implications for Sustainable Forest Management in Europe*. Rome: Euforgen, 211 p.
12. Lindner M., Garcia-Gonzalo J., Kolström M., Green T., Reguera R. (2008) *Impacts of Climate Change on European Forests and Options for Adaptation*: report AGRI-2007-G4-06, 173 p.
13. Lindner M., Maroschek M., Netherer S., Kremer A., Barbati A., Garcia-Gonzalo J., Seidl R., Delzon S., Corona P., Kolstro M., Lexer M., Marchetti M. (2010) Climate change impacts, adaptive capacity, and vulnerability of European forest ecosystems. *Forest Ecology and Management*, 259, pp. 698 – 709.
14. Matras J. (1998) Clonal differences in growth and qualitative features of Scots pine's (*Pinus sylvestris* L.) European populations. In: Scots pine breeding and genetics. *Proceedings of the IUFRO S.02.18 symposium*, 1994, Lithuania, Kaunas, pp. 46 – 53.
15. Read D.J., Freer-Smith P.H., Morison J.I.L., Hanley N., West C.C., Snowdon P. (2009) Combating climate change – a role for UK forests. *An assessment of the potential of the UK's trees and woodlands to mitigate and adapt to climate change.* The synthesis report. The Stationery Office, Edinburgh, 18 p.
16. Seppälä R., Buck A., Katila P. (2009) Adaptation of Forests and People to Climate Change. *A Global Assessment Report*, Tampere, Esa-Print Oy, 224 p.
17. Shutyaev A.M., Giertych M. (2000) Genetic subdivision of the range of Scots pine (*Pinus sylvestris* L.) based on a transcontinental provenance experiment. *Silvae Genetica*, 49 (3), pp. 137 – 151.
18. Solomon S., Qin D., Manning M., Chen Z., Marquis M., Averyt K.B., Tignor M., Miller H.L. (2007) Climate Change 2007: The Physical Science Basis. *Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge University Press, Cambridge, UK, 996 p.

LEAF MORPHOLOGICAL VARIATION OF SESSILE OAK (*QUERCUS PETRAEA* (MATT.) LIEBL.) AND PEDUNCULATE OAK (*QUERCUS ROBUR* L.) IN LITHUANIA

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Abstract
Leaf morphology was assessed in Pajiesys and Seirijai field trials of oaks. Oaks in these trials are the progenies of oak trees (*Quercus* genus) that grow in the Trakas forest of Seirijai district of Alytus forest enterprise of Lithuania. The aim of the study was to determine the number of hybrid trees between the progenies of the Trakas forest in Pajiesys and Seirijai field trials. 251 oaks belonging to 40 half-sib families were sampled. Twenty three leaf morphological variables were measured on each of 5 leaves collected from each tree and analysed by principal component analysis (PCA) and discriminant analysis (DA). The study concluded that *Q. robur* and *Q. petraea* leaves are most clearly identified by six morphological traits. Discriminant function of two traits for oak species separation was proposed. The study has also revealed a high degree of interspecific hybridization in field trials. Study results were compared with earlier reports about hybridization occurring in mixed oak stands in other parts of Europe.
Key words: *Quercus robur*, *Quercus petraea*, leaf morphology, interspecific hybridization.

Introduction

Sessile oak (*Quercus petraea*, (Matt.) Liebl.) and pedunculate oak (*Quercus robur,* L.) cover the areas from the Atlantic up to the regions of continental climate. Since both oak species grow under different environmental conditions, different populations have formed. These populations are distinguished for a high intraspecific genetic variation and differ in phenology, growth speed, shape and other traits (Kleinschmit, 1993). Many species of oak genus are sympatric and interbreeding. E.g. *Quercus petraea* can interbreed with another four European oak species (Borazan and Babaç, 2003; Curtu et al., 2007). Identification of differences between sessile oak and pedunculate oak is complicated as a result of hybridization and introgression between the parental species of these oaks. A lot of morphologically intermediate forms and hybrids emerged as an outcome of introgression process (Wigston, 1975; Rushton, 1978; Rushton, 1979; Iestwaart and Feij, 1989). Kleinschmit et al. (1995) who compared morphological and genetic traits of oaks did not find significant differences between these species and concluded that sessile oak and pedunculate oak can be attributed to different ecotypes of one species, whereas Aas (1996) considered them as taxonomically close species.

Morphological variation of *Quercus robur* and *Quercus petraea* has been of general interest in Europe for many years (Cousens, 1963; Carlisle and Brown, 1965; Olsson, 1975a; Minihan and Rushton, 1984). A lot of attention is being paid to the determination of the most significant distinctive morphological traits of oaks (Olsson, 1975b; Rushton, 1983; Jensen et al., 1984) using various statistical methods (Dupouey and Badeau, 1993; Kleinschmit et al., 1995; Kremer et al., 2002; Viscosi et al., 2009). Many papers include studies on the morphological traits of oaks in different countries. Studies were made in Western Europe, central part of France (Grandjean and Sigaud, 1987), eastern part of France (Dupouey and Badeau, 1993), Holland (Iestwaart and Feij, 1989), central part of Europe (Germany and Poland) (Ass, 1993) and Eastern Europe (Borovics, 1999). Different data collection methods and statistical analyses were used for these studies. Meanwhile, Kremer et al. (2002) included different regions of Western Europe and applied multivariate statistical methods for the separation of morphological traits in their study. The study concluded that stands from south and middle Europe have only a very small part of trees with hybrid traits (2% or less), whereas the number of such trees in Holland, Denmark and Great Britain amounts to 5 – 13%. Greater morphological similarities between these two oak species and shorter petiole of pedunculate oak are typical to stands in northern part of Europe if compared with other parts of Europe. The study confirms previous studies on a higher degree of hybridization in northern part of Europe (Olsson, 1975a; Jensen et al., 2009). Kremer et al. (2002) has modelled a discriminant function suitable to be used in a broad geographical region for the separation of pedunculate oak and sessile oak using the parameters of petiole length and the number of intercalary veins. Although this function is suitable for a fairly broad region, it is not suitable to be used in our region where sessile oak grows at the edge of the area. A separate function suitable for particularly this region, which is distinguished for a huge number of trees with hybrid traits of oaks, is needed. This study also aims to determine the number of hybrid trees between the progenies of the Trakas forest in Pajiesys and Seirijai field trials.

Materials and Methods

Leaves were collected in Pajiesys and Seirijai field trials that are the progenies of the Trakas forest (Alytus district, Veisiejai forest enterprise). Pajiesys field trial is 9 years old, while Seirijai field trial is 5 years old. Leaves from 12 trees of the same age in the area, which is free from sessile oak were also collected for research. Five leaves from each tree were selected in the middle part of the crown at southern side. We used first flush leaves. Leaves were collected from 251 trees belonging to 40 families. Maternal trees were divided into taxonomical groups using computer program EICHE 1.0 (Degen and Reinholdt, 1999) in previous study of oak species composition in Trakas forest (Baliuckas, 2000). Each leaf was assessed according to the following traits (Figure 1):

- *Ten dimensional characters:* Lamina length (LL), petiole length (PL), lobe width (LW), length of lamina from the base to the widest point (WP), sinus width at 1/3 of the leaf (SW1), lobe width at 2/3 of the leaf (LW1), sinus width at 2/3 of the leaf (SW2), lobe width at 3/3 of the leaf (LW2), lamina width at 1/4 of leaf length (L25), lamina width at 3/4 leaf length (L75)
- *Two counted variables:* the number of intercalary veins (NV), number of lobes (NL)
- *Two observed variables*: Abaxial laminar pubescence (PU), (1 – no pubescence, 3 – dense pubescence) was assessed with a microscope (x4) and took into account both simple and stellate pubescence; basal shape of the lamina (BS) (varying from 1 to 9) (according to Kremer et al. 2002).
- *Nine transformed variables:*

  Lamina shape or obversity OB = 100 × WP / LL,
  Petiole ratio PR = 100 × PL/(PL + LL),
  Lobe depth ratio LDR = 100 × (LW – SW1) / LW,
  Percentage venation PV = 100 × NV / NL,
  Lobe width ratio LWR = 100 × LW / LL (according to Kremer et al. 2002),
  Lobe width and lobe size ratio: L75/L25, LW2/LW1, SW2/SW1, LW1/SW2.

Statistical Analysis

The dependence of lamina length on other morphological traits is estimated by Pearson correlation. Twenty three morphological traits of leaves were analysed by PC-ORD principal component analysis (PCA) using Pearson correlation and distance-based biplot. The differences between the averages of morphological traits for different species were estimated using single factor dispersion analysis. The use of SAS STEPDISC procedure (slentry=0.05) permitted to discover the traits of leaves, which separate species under research most. The attribution of individuals to one or another species according to discriminant functions proposed by other authors, as well as to the functions proposed by us, performed SAS DISCRIM procedure.

Results and Discussion

The correlation between lamina length and all other traits were computed at the leaf level over the whole data set. Dimensional characters showed a strong positive correlation with lamina length, whereas all other traits were not influenced by size effects. A very strong correlation was almost among all the traits (ranging from 0.59 to 0.9).

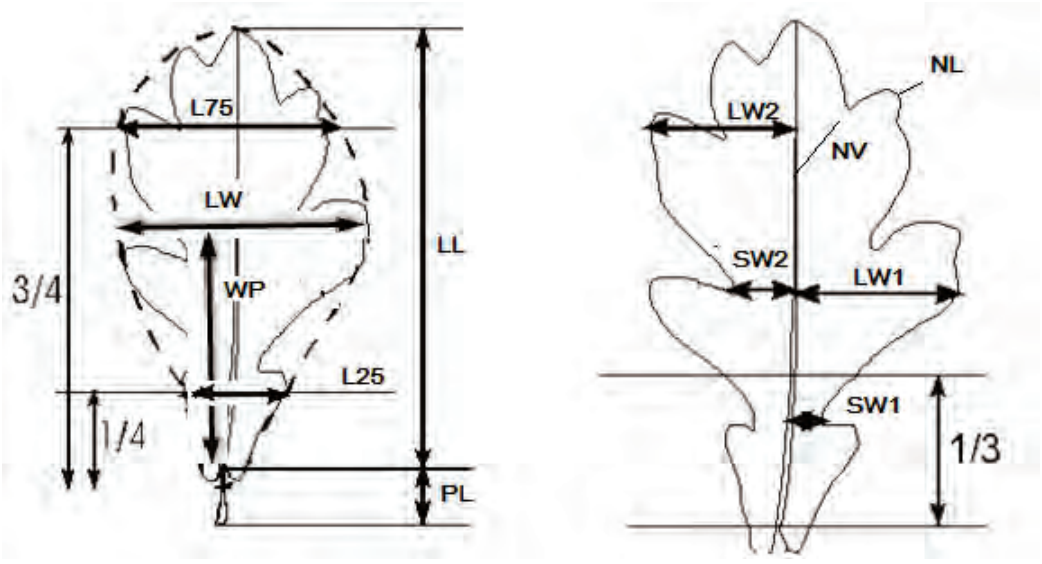

Figure 1. Characteristics of morphological traits of leaves (by Degen and Reinholdt, 1999).

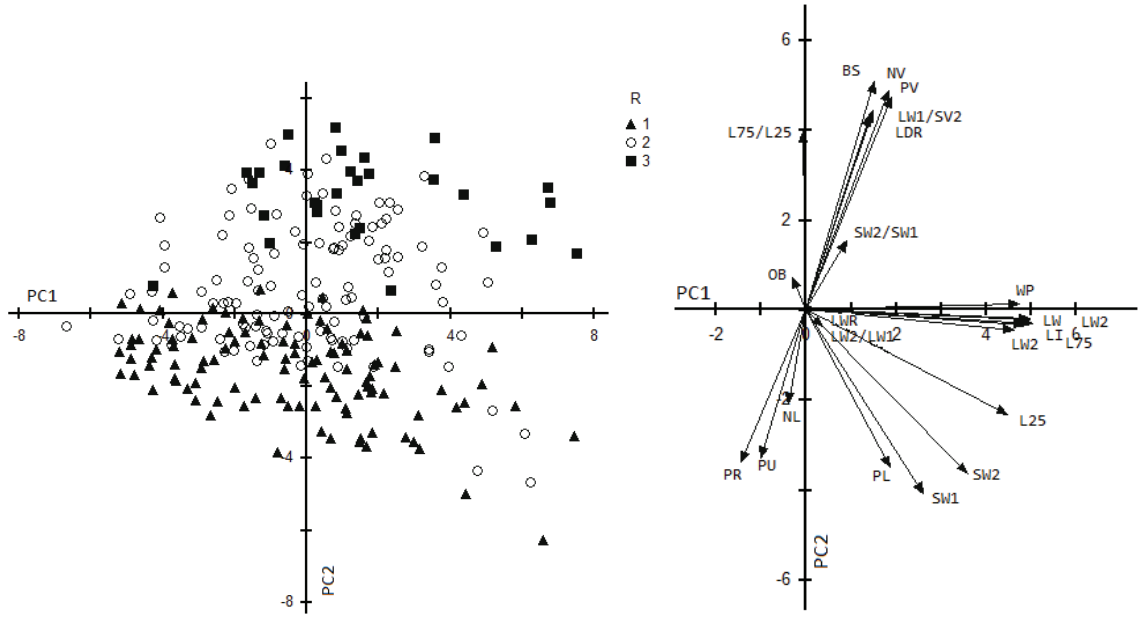

Figure 2. Ordination diagrams (PCA) using 23 leaf traits. On the left, distribution of leaves at axes PC1 and PC2: 1 – sessile oak, 2 – interspecific hybrid, 3 – pedunculate oak.

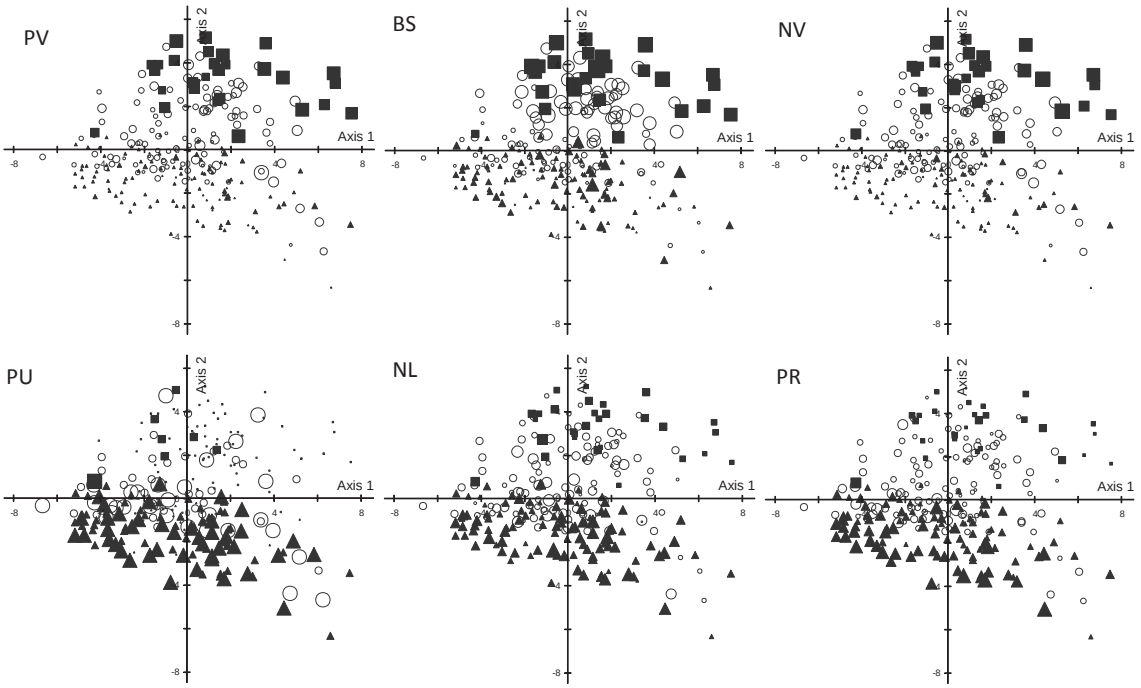

Figure 3. The main morphological traits of leaves defining oak species according to their numeric value size. The bigger the figure is, the higher numeric value of the trait is. PV – percentage of venation, BS – basal shape of the lamina, NV – number of intercalary veins, PU – abaxial laminar pubescence, NL – number of lobes, PR – petiole ratio. Marking is the same as in Figure 2.

Correlation with only PL and SW1 was on the average 0.39 and 0.41, respectively. As far as observed and transformed traits are concerned, the correlation was low (from -0.29 to 0.27). An interesting observation was that the morphological traits that were used for species identification (PU, BS, PL, NV, PR) showed only weak correlation with LL. That confirms the computations made by Kremer et al. (2002), who used slightly less (14) traits of leaves.

Other studies were made using the averages of 5 leaves collected from each tree. Figure 2 shows tree projections PCA at two axes coordinate, which is described with 53.93% variation, i.e. 33.75% variation at PC1 axis and 20.18% variation at PC2 axis and marked in the drawing in different figures. Vectors of morphological traits of leaves which show that pedunculate and sessile oak are mostly separated by BS, NV, PV, LW1/SW2, LDR, PR, PU, NL are presented. Larger basal shape of the lamina, higher number of intercalary veins and larger lobes are typical to pedunculate oak, whereas sessile oak is distinguished for a higher number of lobes, denser abaxial laminar pubescence, higher number of lobes and longer petiole. These traits intercorrelate most. Figure 3 depicts the most distinctive traits between the species according to variations of their numeric values.

The significance of parameters for species identification is presented in Table 1. The parameters, those numerical values that differ between the species most, are presented in the first four rows (BS, PV, NV, PU). PR, LW1/SW2, L75/L25, NL, LDR, LL, WP, LW1, L75, LW parameters between the species differ on the average, whereas the difference among the parameters PL, SW1, LW2, L25, SW2 by species is significant, but is not huge. Only four parameters (LW2/LW1, SW2/SW1, LWR and OB) presented last in the table do not differ significantly between the species.

Kremer et al. (2002) proposed to use the following discriminant function for oak species identification:

$$ID = 357 – (97 \times PL) + (205 \times NV), \quad (1)$$

where PL – petiole length (mm), NV – number of intercalary veins.

The authors of the aforementioned function obtained a 99% match using this function. Negative values for sessile oak and positive values for pedunculate oak were obtained, whereas hybrids have distributed according to a greater similarity to one

Table 1

Values of the averages of leaf parameters, according to criterion F

Parameters	P	H	B	F	p
BS	7.54	4.08	3.11	179.1	0.000
PV	70.11	36.14	20.35	104.0	0.000
NV	6.66	3.55	2.22	96.9	0.000
PU	1.24	1.97	2.39	59.8	0.000
PR	5.20	6.56	8.06	32.5	0.000
LW1/SW2	216.38	176.56	160.46	32.1	0.000
L75/L25	176.69	149.45	151.14	30.5	0.000
NL	9.94	10.45	11.65	25.2	0.000
LDR	88.45	84.58	84.42	20.5	0.000
LL	88.43	87.30	74.31	13.3	0.000
WP	55.65	53.81	46.52	13.0	0.000
LW1	26.54	24.69	21.68	12.4	0.000
L75	48.74	44.98	40.51	11.3	0.000
LW	52.55	49.30	43.76	11.2	0.000
PL	4.83	5.98	6.41	9.0	0.000
SW1	6.03	7.42	6.53	6.1	0.002
LW2	25.12	22.99	21.26	5.8	0.003
L25	28.96	31.25	27.61	4.2	0.016
SW2	13.10	14.97	13.96	4.0	0.020
LW2/LW1	95.63	94.02	101.15	2.5	0.081
SW2/SW1	239.22	228.71	232.16	0.6	0.566
LWR	59.57	58.47	60.13	0.6	0.575
OB	62.88	62.96	63.94	0.2	0.785

of the species. The results of these functions in our study showed 73% attribution to sessile oak and 75% to pedunculate oak. However, negative and positive values did not reflect the species. Therefore, another function has been chosen for our data analysis, which has permitted to obtain a similar distribution according to negative and positive values, which were also obtained by Kremer et al. (2002):

$$ID = – (125 \times PL) + (200 \times NV). \quad (2)$$

Sessile oak matched with 68% and pedunculate oak matched with 78% cases. Upon STEPDISC procedure, 8 traits which significantly identified oak species, were distinguished: PU, NV, BS, NL, LL, LW2, PV, L75/L25 (explained 45% of variation) (Table 2). Since petiole length was not included in these traits, we have tried to use NL in the discriminant function. Having used the function so that negative values would match sessile oak, while positive values would match with pedunculate oak, the following function was obtained:

$$ID = 100 – (100 \times NL) + (200 \times NV) \quad (3)$$

73% of the cases matched with sessile oak and 73% with pedunculate oak. A conditionally worse match obtained by Kremer et al. (2002) can be explained by a higher proportion of hybrids in peripheral (marginal) populations showed by our other studies as well as studies made by scientists from northern Scandinavian countries (Olsson, 1975a; Baliuckas, 2000; Jensen et al., 2009). A great part of mismatch in our study could have also resulted due to a young age of oak trees. In the similar study of pure sessile and pedunculate oak species leaf morphology by Ponton et al. (2004) was revealed that discriminant function for young seedlings gave not as reliable results as for adult trees. It was shown by Viscosi and Fortini (2011) study on white oak species that unclassified or hybrid trees leaf shape traits correlate with environmental factors. Elliptic Fourier analysis could be of particular use in the analysis of leaf shape variability and discrimination in the subgenus *Quercus* when visualizing leaf shape attributes (Viscosi and Fortini, 2011).

Having researched the morphological traits, the species match of the progenies of the Trakas forest that grow in field trials has been defined (Table 3). The generalization of all results showed an increase of hybrid oaks among the progenies of the Trakas forest. 80% hybrids were detected among the progenies of pedunculate oak and 48% hybrids among the progenies of sessile oak. At the time when hybrid maternal trees accounted for 28% of the total number of oaks, 58% of hybrid oaks were identified among their progenies. That confirms the hypothesis which has been raised more than once by researchers who argued that hybridization processes between *Q. robur* and *Q. petraea* are much more intense at the peripheries of species areas and especially in their spread edges if compared with the central part of Europe (Dupouey

Table 2

Traits distinguished by STEPDISC procedure, which separate oak species most

Traits	R^2	F	p
BS	0.2580	42.08	<0.0001
LL	0.1046	14.14	<0.0001
NL	0.0815	10.74	<0.0001
PL	0.0773	10.13	<0.0001
PV	0.0572	7.35	0.0008
LW2	0.0530	6.78	0.0014
L75/L25	0.0405	5.11	0.0067
NV	0.0435	5.48	0.0047

Table 3

Species match between maternal trees and their progenies in field trials

Maternal tree	Number of progenies, pcs. (%)			Total number of progenies, pcs. (%)
	Pedunculate	Hybrids	Sessile	
Pedunculate oak	10 (20)	39(80)	0	49 (20)
Hybrid	3 (5)	39 (59)	24 (36)	66(28)
Sessile oak	0	60 (48)	64 (52)	124(52)
Total	13 (5)	138 (58)	88 (37)	239 (100)

and Badeau, 1993). Studies made in the Trakas forest in Lithuania showed 37% of hybrids (Baliuckas, 2000), while the percentage of hybrids amounts to 37% in the southern part of Sweden (Olsson, 1975a). A fairly high degree of hybridization (15 – 55 %) was determined after the study in the Jutland forest in Denmark, whereas hybridization was higher in the northern part of this area (Jensesn et al., 2009). Our study coincides with the studies of other authors, who also speak about a high degree of hybridization between *Q. robur* and *Q. petraea* - Carlisle and Browm (1965), Wigston (1975) in Sweden, Rushton (1978, 1979, 1983), Minihan and Rushton (1984) in the United Kingdom, Kissling (1980 a,b; 1983) in Sweden. Meanwhile, different results were obtained in similar studies made in the central Europe (Aas, 1993; Steinhoff, 1998; Streiff et al., 1999). For example, studies made in Romania's stand with the prevalence of 4 oak species (*Quercus robur*, *Q. petraea*, *Q. pubescen*s and *Q. frainetto)* showed that only 16 (~6%) of single trees had intermediate morphological or combined traits of different species (Curtu et al., 2007). The same observations were obtained in other oak species hybridization studies (Semerikov et al., 1988). Clinal change of introgression towards north is noticed.

Conclusions

1. Discriminant function according to which 73% of cases matched with sessile oak and 73% with pedunculate oak was obtained (in comparison with the groups of species formed using all morphological traits studied). According to this function, we can assess the dependence of the progenies of the Trakas forest on one or another species.
2. The study of morphological traits of leaves permitted to determine that the share of hybrid oaks has grown by 30% compared with maternal trees between the progenies of the Trakas forest that grow in field trials.

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References

1. Aas G. (1993) Taxonomical impact of morphological variation in *Quercus robur* and *Q. petraea*: a contribution to the hybrid controversy. *Annales des Sciences Forestières.* Paris, 50, pp. 107 – 114.
2. Aas G. (1996) Morphologische and okologische Variation mitteleuropaischer *Quercus*-Arten*:* Ein Beitrag zum Verstandnis der Biodiversitat (Morphological and ecological variation of *Quercus* species in Central European: a contribution to the understanding of Biodiversity). Habilitation Thesis, ETH Zurich. (in German).
3. Baliuckas V. (2000) Paprastojo (*Quercus robur*) ir bekočio (*Q. petraea*) ąžuolo rūšių introgresija Trako miške (Introgression of pedunculate oak (*Quercus robur*) and sessile oak (*Q. petraea*) in forest Trakas). *Botanica Lithuanica*, 6(4), pp. 375 – 387. (in Lithuanian).
4. Borazan A., Babaç M.T. (2003) Morphometric leaf variation in oaks (*Quercus*) of Bolu, Turkey. *Annales Botanici Fennici*, 40, pp. 233 – 242.
5. Borovics A. (1999) Separability of pedunculate oak and sessile oak aggregate: a contribution to the hybrid and small species estimation. Proceedings of the Forest Research Institute, 89, pp. 93 – 110.
6. Carlisle A., Brown A.M.F. (1965) The assessment of the taxonomic status of mixed oaks (*Quercus* ssp.) populations. *Watsonia,* 6, pp. 120 – 127.
7. Cousens J.E. (1963) Variation of some diagnostic characters of the sessile and pedunculate oaks and their hybrids in Scotland. *Watsonia,* 5, pp. 273 – 286.
8. Curtu A.L., Gailing O., Finkeldey R. (2007) Evidence for hybridization and introgression within a species-rich oak (*Quercus* spp.) community. *BMC Evolutionary Biology*, *7*: 218, 15 p. Available at: http://www.biomedcentral.com/1471-2148/7/218, 14 October 2011.
9. Degen B., Reinholdt B. (1999) Eiche 1.0 Programm zur Unterscheidung von Stiel-und Traubeneiche anhand blattmorphologisher Merkmale (Eiche 1.0 Program to distinguish pedunculate and sessile oaks based on leaves morphological characteristics). [CD-ROM], Institut für Forstgenetik Ökologische Genetik, Germany. (in German).
10. Dupouey J.L., Badeau V. (1993) Morphological variability of oaks (*Quercus robur* L, *Quercus petraea* (Matt) Liebl, *Quercus pubescens* Willd) in northeastern France: preliminary results. In *Annales des Sciences Forestières* (Vol. 50, No. Supplement, pp. 35s – 40s. EDP Sciences.
11. Grandjean G., Sigaud P. (1987) Contribution à la taxonomie et à l'écologie des chênes du Berry (Contribution to the taxonomy and ecology of oaks in Berry). *Annales des Sciences Forestières.* Paris, 44, pp. 35 – 66. (in French).

12. Iestwaart J.H., Feij A.E. (1989) A multivariate analysis of introgression between *Q. robur* and *Q. petraea* in The Netherlands. *Acta Botanica Neerlandica*, 38, pp. 313 – 325.
13. Jensen R.J., DePiero R., Smith B.K. (1984) Vegetative characters, population variation and the hybrid origin of *Quercus ellipsodalis*. *American Midland Naturalist*, 111, pp. 364 – 370.
14. Jensen R.J., Laresen A., Nielsen L.R., Cottrell J. (2009) Hybridization between *Quercus robur* and *Q. petraea* in a mixed oak stand in Denmark. *Annals of Forest Science*, 66 (706), 12 p. Available at: www.afs-journal.org/10.1051/forest/2009058, 02 November 2013.
15. Kissling P. (1980a) Un réseau de corrélations entre les chênes (*Quercus*) du Jura (A network of correlations between oaks (*Quercus*) of Jura). *Bericht der Schweizerischen Botanischen Gesellschaft. Bulletin de la Société Botanique Suisse. Basel, Geneva, Zurich,* 90, pp. 1 – 28. (in French).
16. Kissling P. (1980b) Clef de détermination des chênes médioeuropéens (*Quercus* L). (Key to determining the oaks of central Europe (*Quercus* L)). *Bericht der Schweizerischen Botanischen Gesellschaft. Bulletin de la Société Botanique Suisse. Basel, Geneva, Zurich,* 90, pp. 29 – 44. (in French).
17. Kissling P. (1983) Les chênaies du Jura central suisse (Oak forests of central Jura canton). Thesis, Université de Lausanne, Switzerland, 400 p. (in French).
18. Kleinschmit J. (1993) Intraspecific variation of growth and adaptive traits in European oak species. *Annales des Sciences Forestières*. Paris , 50, pp. 166 – 185.
19. Kleinschmit J.R.G., Bacilieri R., Kremer A., Roloff A. (1995) Comparison of morphological traits of pedunculate oak (*Q. robur* L.) and sessile oak (*Q. petraea* (Matt.) Liebl. *Silvae Genetica*, 44, pp. 256 – 269.
20. Kremer A., Dupouey J.L., Deans J.D., Cottrell J., Csaikl U., Finkeldey R., Espinel S., Jensen J., Kleinschmit J., Van Dam B., Ducousso A., Forrest I., de Heredia U.L., Lowe A.J., Tutkova M., Munro R.C., Steinhoff S., Badeau V. (2002) Leaf morphological differentiation between *Quercus robur* and *Quercus petraea* is stable across western European mixed oak stands. *Annals of Forest Science*, 59, pp. 777 – 787.
21. Minihan V.B., Rushton B.S. (1984) The taxonomic status of oaks (*Quercus* ssp.) in Breen Wood, Co Antrim, Northern Ireland. *Watsonia,* 15, pp. 27 – 32.
22. Olsson U. (1975a) A morphological analysis of phenotypes in populations of *Quercus* (*Fagaceae*) in Sweden. *Botaniska Notiser,* 128, pp. 55 – 68.
23. Olsson U. (1975b) The structure of stellate trichomes and their taxonomic implication in some *Quercus* species (*Fagaceae*). *Botaniska Notiser,* 128, pp. 412 – 424.
24. Ponton S., Dupouey J.-L., Dreyer E. (2004) Leaf morphology as species indicator in seedlings of *Quercus robur* L. and *Q. petraea* (Matt.) Liebl.: modulation by irradiance and growth flush. *Annals of Forest Science*, 61, pp. 73 – 80.
25. Rushton B.S. (1978) *Quercus robur* L. and *Quercus petraea* (Matt.) Liebl.: a multivariate approach to the hybrid problem. 1. Data acquisition, analysis and interpretation. *Watsonia,* 12, pp. 81 – 101.
26. Rushton B.S. (1979) *Quercus robur* L. and *Quercus petraea* (Matt.) Liebl.: a multivariate approach to the hybrid problem. 2. The geographical distribution of population types. *Watsonia,* 12, pp. 209 – 224.
27. Rushton B.S. (1983) An analysis of variation of leaf characters in *Quercus robur* L. and *Quercus petraea* (Matt.) Liebl. population samples from Northern Ireland. *Irish Forest*. 40, pp. 52 – 77.
28. Semerikov L.F., Glotov N.V., Zhivotovskii L.A. (1988) Example of effectiveness of analysis of the generalized variance of traits in trees. *The Soviet Journal of Ecology (USA),* 18, pp. 140 – 143.
29. Steinhoff S. (1998) Kontrollierte Kreuzungen zwischen Stiel- und Traubeneiche: Ergebnisse und Folgerungen (Controlled crosses between pedunculate and sessile oak: results and conclusions). *Allgemeine Forstund. Jagdzeitung*, 169, S. 163 – 168. (in German).
30. Streiff R., Ducousso A., Lexer C., Steinkellner H., Gloessl J., Kremer A. (1999) Pollen dispersal inferred from paternity analysis in a mixed oak stand of *Quercus robur* L. and *Q. petraea* (Matt.) Liebl. *Molecular Ecology*, 8, pp. 831 – 841.
31. Viscosi V., Fortini P. (2011) Leaf shape variation and differentiation in three sympatric white oak species revealed by elliptic Fourier analysis. *Nordic Journal of Botany*, 29, pp. 632 – 640.
32. Viscosi V., Lepais O., Gerber S., Fortini P. (2009) Leaf morphological analyses in four European oak species (*Quercus*) and their hybrids: A comparison of traditional and geometric morphometric methods. *Plant Biosystems, 143*(3), pp. 564 – 574.
33. Wigston D.L. (1975) The distribution of *Q. robur* L., *Q. petraea* (Matt.) Liebl. and their hybrids in south-western England. 1. The assessment of the taxonomic status of populations from leaf characters. *Watsonia,* 10, pp. 345 – 369.

REGIONAL DIFFERENCES OF FINAL FELLING SAWLOG OUTCOME IN LATVIA

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Abstract
Pine, spruce and birch stem's quality is different in regions of Latvia, but the differences are not included in the tables and models of assortment outcome. Therefore, it is not possible to predict accurately the outcome of round wood assortments. The aim of the research was to evaluate the regional differences of final felling sawlog outcome for Scots pine (*Pinus sylvestris* L.), Norway spruce (*Picea abies* (L.) Karst.) and birch (*Betula* spp.) in Latvia and to set the regions with a different sawlog outcome. Data from 1645 final felling areas was used for pine, 1202 for spruce and 1531 for birch from the years 2010 – 2012. Firstly, the sawlog outcome of 97 territorial units was set by using the data of the final felling areas sawlog outcome of pine, spruce and birch. Secondly, territorial units with a similar sawlog outcome were consolidated in regions. The smallest regional difference of sawlog outcome was found for spruce (9.4%), slightly larger for pine (10.5%) and the largest difference for birch (16.2%). Three regions with the different sawlog outcome were found for Scot pine, six for Norway spruce and seven for birch. Several spruces and birch regions have similar sawlog outcome but those do not have borders. They are between regions with higher or lower sawlog outcome. Sawlog outcome of neighbouring regions differ for at least 4 – 5%.
Key words: sawlog outcome, region, *Pinus sylvestris*, *Picea abies*, *Betula* spp.

Introduction

In various studies of pine, spruce and birch stems quality it was found out that the quality differs in the regions of Latvia, but regional quality differences are not included in the round wood assortment tables and models. Therefore, it is not possible to predict accurately the outcome of round wood assortments in the various regions of Latvia.

The regional differences of pine stems quality are being the most widely studied, both, comparing the final felling stands and comparing stands in breeding trials. Comparing the final felling age pine stands for high quality sawlog outcome estimation, it was found out that the stands in north east Latvia are better than in north west Latvia (Zālītis and Špalte, 1998). A similar study was also realized later and researchers found out that stands of east have higher branch-free stem sections than in the south of Latvia (Zālītis and Špalte, 2000). 28 years old stands were compared in breeding trials in four Latvian regions (west, central, south-east and north-east). The researcher found out that stands of the west have less straight stems and have higher branch thickness, but stands of the north-east have more straight stems and less thick branches (Baumanis et al., 2001). Partially similar knowledge was acquired in following breeding trials. Length of the stems branch-free section and quality, branch angle and branch thickness was compared in 21 pine stands. It was found out that the east populations are better than west populations, only stem straightness does not differ between populations (Neimane, 2009a; Neimane et al., 2009b).

33 final felling age spruce stands were compared for estimation of spruce regional quality differences in two regions. Researchers found out that the outcome of the high quality sawlog does not differ between the west and the east parts of Latvia (Špalte and Zālītis, 2003).

Regional quality differences of birch stems were investigated in other study with a similar principle. The high quality veneer logs outcome was compared in birch stands. The study was based on regression function prepared from 760 measured birch stems. High quality veneer logs outcome of birch stands was set with regression function (factors: the diameter and height). Forest inventory data of 257 forest districts of Latvia was exploited. Researchers found out that there are quality differences in the regions of Latvia. Stands with lower veneer logs outcome mainly are located in the western part of Latvia (Zālītis et al., 2002). The birch stands quality regional differences were evaluated with the same methodology by using the National forest inventory data. The researcher found out that there is a significant difference in the quality between the east Latvia and the west Latvia. Lower veneer logs outcome is in the western part of Latvia (Zālītis, 2008).

In the study of pine, spruce and birch stems surface it was also found out that there are regional differences. However, the amount of data is not enough for general conclusions (Dubrovskis et al., 2013).

Different results of pine, spruce and birch steams quality were found using the National forest inventory data. To characterize the quality, the branch-free section of stem was used. In the study it was found out that the branch-free section of stems of pine, spruces and birch does not differ between western, eastern and southern regions (Lībiete, 2006).

Conclusive findings were not found about regional differences of stems quality and round wood assortments outcome. In addition, different breakdown of regions were applied in studies.

Nowadays the round wood production data is stored in databases that open up the opportunity to use many of the felling area data on a wide territory. The regional differences of round wood assortments outcome can be found out by using the whole Latvia's territory data of final felling round wood production.

The aim of the research was to evaluate the regional differences of final felling sawlog outcome for Scots pine (*Pinus sylvestris* L.), Norway spruce (*Picea abies* (L.) Karst.) and birch (*Betula* spp.) and set the regions with a different sawlog outcome in Latvia.

Materials and Methods

The study was carried out in the year 2013. Several years' data of round wood productions was used. The territory of Latvia was divided into 97 territorial units and there was calculated average sawlog outcome of each species. Territorial areas with similar sawlog outcome were consolidated.

Materials for this study were taken from JSC 'Latvijas valsts meži' 2010 – 2012 years final felling areas throughout the whole territory of Latvia. For each final felling area the data was collected; firstly, forest inventory data, secondly, round wood assortments or stands volume and thirdly, the structure of each tree species.

The largest part of felling areas data of round wood assortments was collected from harvester production files. During tree felling, harvesters collect data about each felled tree: species, number of trees, produced round wood assortments volume and assortment type: firewood, pulpwood, sawlogs (2 – 8 diameter and quality classes), veneer logs. For simplification the birch veneer logs were combined with the birch sawlogs. Minimal diameter of birch veneer logs were changed in the middle of the year 2011. In order to prevent the birch veneer logs outcome differences over the years, data of the year 2011 was excluded from the calculations. The proportion of the year 2010 birch veneer logs outcome was increased by 3.74%. The percentage was obtained from relationship between the year 2010 and 2012 proportion of veneer logs at the same age, the same site index and the same forest type stands.

Pine, spruce and birch sawlog outcome was calculated as the proportion of sawlog volume of each species from the total round wood assortment volume of each species. In pine and spruce sawlog category there was the sawlog with the diameter larger than 10 cm (not included low quality sawlog - sleepers) included, in the birch sawlog category there were birch veneer logs and sawlog with the diameter larger than 12 cm included.

Round wood assortment volume assessment from stands measured by callipers were used for stands, which did not have production files of harvesters. The distribution of round wood assortments was not available in stands measured by callipers. But, each tree had been included into one of the five groups: thick, medium and small sawlog, pulpwood and firewood. The sawlog outcome was calculated from the thick sawlog volume multiplied by coefficients: pine 0.86, spruce 0.84 and birch 0.76. Coefficient values were obtained by calculating the difference between the sawlog volume and round wood assortment volume of thick sawlog at the same age, the same site index and the same forest type stands. It should be noted that it is impossible to find the correlation between the two volumes; therefore, for each species there was calculated one – the average coefficient.

Forest type groups, site index and ages of each species first stage trees were stated from forest inventory data in the felling year. Felling area can be created from multiple stands, which may include stands with different age, forest type, sit index. So, the problem is setting average values. Therefore, the felling areas that are created in one stand or in part of one stand were used in the research. Site index was set by the dominant tree species.

The felling areas larger than 1ha were used to reduce possible risks that the whole stand could not be included in the felling area. Additionally, the tress of first storey and tress of second storey are not possible to divide (sawlog outcome from second storey trees is lower) for felling areas felled by harvesters. Therefore, felling areas with minimum 50 $m^3 ha^{-1}$ of pine or birch round wood assortments, for spruce 100 $m^3 ha^{-1}$ of spruce round wood assortments, were chosen for pine and birch sawlog outcome calculations.

Regional differences of sawlog outcome by using species dominant site index and forest type were set. The data of each species was supplemented with data of those site indexes and forest types which did not differ from the characteristic values of the species. The same principle was used to select the age range. Data used for study is showed in Table 1.

The smallest territorial unit of JSC 'Latvijas valsts meži' – a block district was used in order to determine the regional differences of sawlog outcome. The number of block district is 97 with the average size of 15 000 ha, and it covers practically the whole territory of Latvia. The average sawlog outcome and representativeness of sample were calculated for each species, for each block district. Then, block districts were consolidated (approximately ten iterations) in regions with a similar sawlog outcome. After each consolidation sawlog outcome and representativeness of sample were recalculated for regions of consolidated block districts. Block districts were combined in regions until the sawlog outcome of each species between regions statistically differ significantly, it was determined by T-test.

Table 1

Characteristics of species site index, groups of forest types and number of felling units used for study

Indicator	Pine	Spruce	Birch
Sit index	I un II	I^a, I un II	I^a un I
Age, years	101 – 120	81-100	71-90
Groups of forest types	Dry, wet mineral soils, drained mineral soils	All	Dry, drained mineral soils
Number of felling areas	1645	1202	1531

At first, neighbouring block districts were combined with less than 3 – 4% differences of sawlog outcome and at the least moderate representativeness of sample. Finally, block districts were consolidated (single and multiple existing together) whose representativeness of sample was poor. Individual block districts were added to the nearest group of block districts, based on assessment of territorial configuration. Several block districts existing together were consolidated gradually and consolidated with similar value groups.

Finally, correlation was tested between species regional differences of the sawlog outcome by using correlation analysis. The region's average sawlog outcome was used for comparison of each block district.

Results and Discussion

Data of the final felling areas (measured by harvesters or callipers) was used for setting pine, spruce and birch regions with different sawlog outcome (Figure 1, 2, 3) and the regional differences of final felling sawlog outcome for pine, spruce and birch in Latvia estimated. Regions have complex geographical forms; therefore, codes were assigned to them. Three regions for pine, six for spruce and seven for birch with different sawlog outcome were found. Each pine region has a different sawlog outcome. Several spruces and birch regions have similar sawlog outcome, but those do not have borders (they are between regions with higher or lower sawlog outcome).

Sawlog outcome values and coefficients of variation are shown for regions of each tree species in Table 2. The smallest regional difference of sawlog outcome was found for spruce (9.4%), slightly larger for pine (10.5%) and the largest for birch (16.2%). It should be noted that coefficient of variation of sawlog outcome for birch is 2.9 times and for spruces 1.6 times greater than the coefficient of variation of

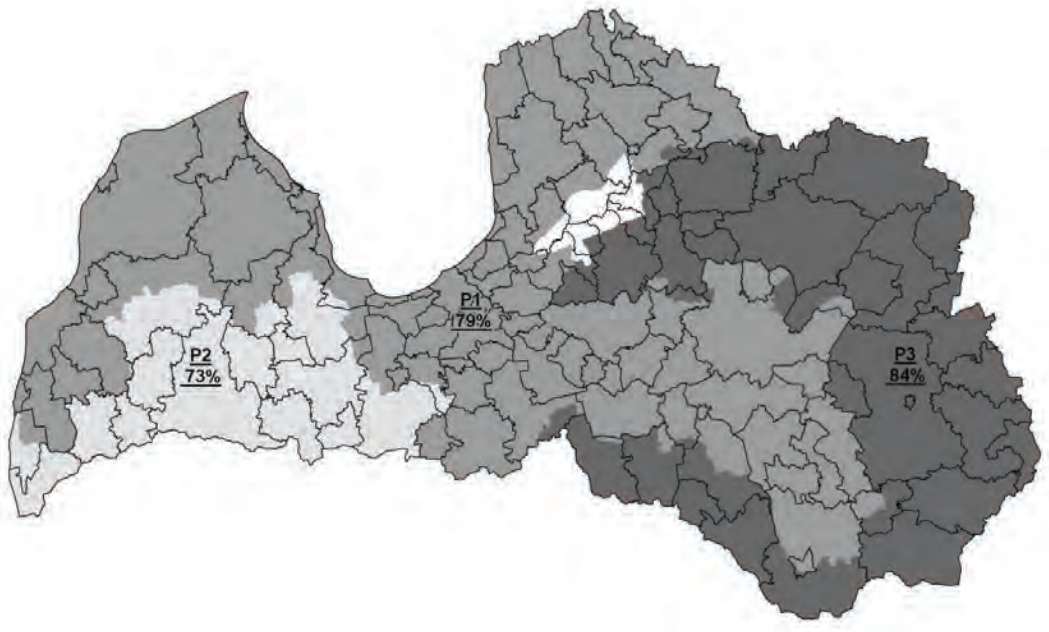

Figure 1. Scot pine (*Pinus sylvestris* L.) regions of final felling sawlog outcome in Latvia (regions with sawlog outcome: 70-75%, 75-80%, 80-85%, borders of Latvia's administrative units, codes of regions: P1, P2, P3).

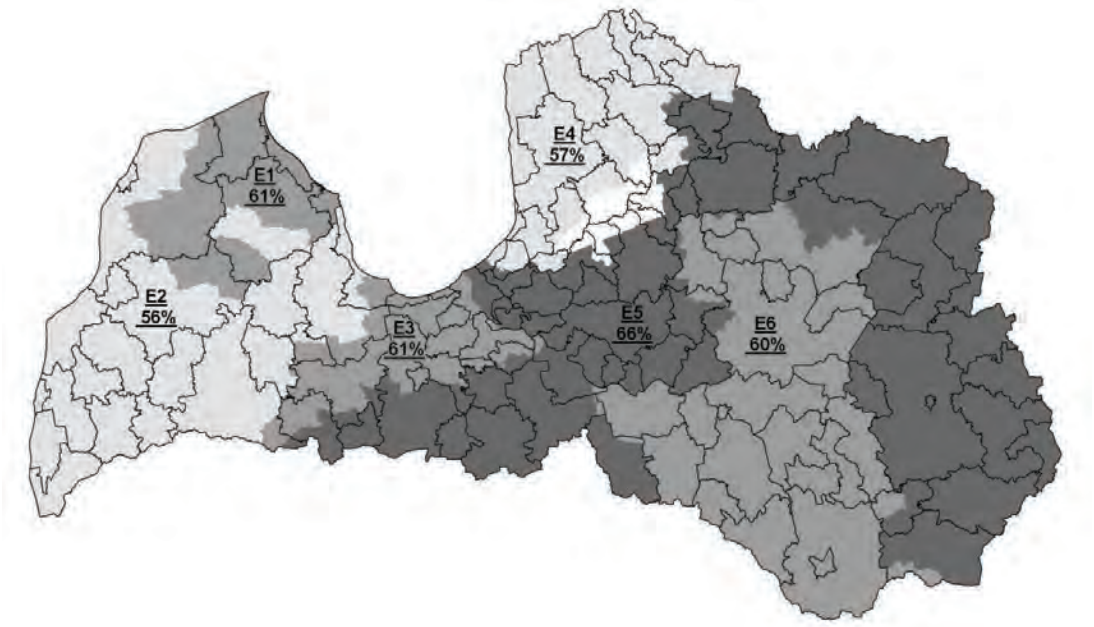

Figure 2. Norway spruce (*Picea abies* (L.) Karst.) regions of final felling sawlog outcome in Latvia (regions with sawlog outcome: 55-60%, 60-65%, 65-70%, borders of Latvia's administrative units, codes of regions: E1, E2, E3, E4, E5, E6).

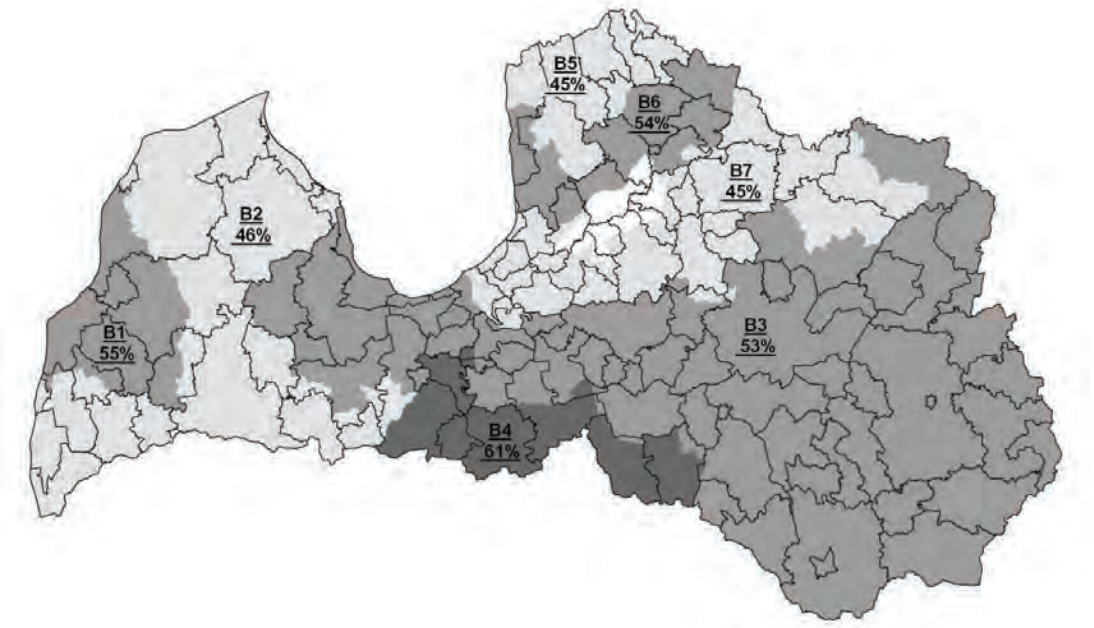

Figure 3. Birch (*Betula* spp.) regions of final felling sawlog outcome in Latvia (regions with sawlog outcome: 45-50%, 50-55%, 60-65%, borders of Latvia's administrative units, codes of regions: B1, B2, B3, B4, B5, B6, B7).

sawlog outcome for pine. This means that the birch sawlog output values are much more dispersed around the sample mean value. One of the reasons could be that Latvia has two birch species: Silver birch (*Betula pendula* Roth.) and Downy birch (*Betula pubescens* Ehrh.), but their data is not counted separately. Zālītis (2002) research confirms that the veneer log outcome from Silver birch is 47% and Downy birch 35% (Zālītis et al., 2002).

For all species neighbouring sawlog outcome regions differ at least 4 – 5% and do not have borders between regions with similar values. The difference

Table 2

Statistics of final felling sawlog outcome regions

Species	Regions	Sawlog outcome and standard error,%	Sawlog outcome coefficients of variation
Scot pine (*Pinus sylvestris* L.)	P1	79.4 ± 0.2	0.08
	P2	73.0 ± 0.8	0.16
	P3	83.5 ± 0.3	0.07
	Average	79.4 ± 0.2	0.10
Norway spruce (*Picea abies* (L.) Karst.)	E1	61.7 ± 0.6	0.13
	E2	56.2 ± 0.6	0.19
	E3	61.3 ± 1.0	0.15
	E4	57.4 ± 1.4	0.18
	E5	65.6 ± 0.4	0.13
	E6	60.3 ± 0.6	0.14
	Average	61.2 ± 0.3	0.16
Birch (*Betula* spp.)	B1	55.0 ± 1.8	0.30
	B2	46.3 ± 0.9	0.34
	B3	53.2 ± 0.5	0.25
	B4	61.2 ± 1.3	0.21
	B5	45.0 ± 1.4	0.32
	B6	54.4 ± 1.5	0.26
	B7	45.7 ± 1.1	0.30
	Average	51.1 ± 0.4	0.29

was significant ($p<0.01$) between average sawlog outcome of neighbouring regions (pine P1/P2 and P1/P3; spruce E1/E2, E2/E3, E3/E5, E4/E5, E5/E6; birch B1/B2, B2/B3, B2/B4, B3/B4, B3/B7, B5/B6, B6/B7). Thus, it is an opportunity to use the regions of sawlog outcome for improvement of round wood assortment models.

The study findings suggest that all tree species are equal to the general trend – to the east increase the sawlog outcome. This is also confirmed by other study's findings, the worst quality of pine stands is in the south, the medium quality in the west and the highest quality is in the east (Zālītis and Špalte, 2002). It coincides with breeding researches in which it was found out that lower pine stands quality is in the west, the highest is in the east (Baumanis et al., 2001; Neimane et al., 2009b). Also, on the birch stands there are similar results of the studies that confirm that the stem quality is the worst in the western part of Latvia (Zālītis et al., 2002; Zālītis, 2008). According to Lībiete (2006), the pines, spruce and birch stem quality (branch-free sections) should not show the quality differences, but results acquired in this study show the opposite results. However, above mentioned studies assessed stems branch-free section or sawlog outcome of the highest quality, which differs from our study, used sawlog classification.

The correlation between tree species regions was examined, comparing all species sawlog outcome values. Correlation between pine and spruce regions is moderate ($r=0.49$; $p<0.05$), between the birch and spruce regions is weak ($r=0.21$; $p<0.05$) and between birch and pine regions no correlation ($r=0.19$; $p>0.05$). Study results allow to conclude that coniferous trees regional differences are partially determined by similar factors, but birch regional differences are determined by different factors. In further studies the possible factors should be analysed.

Conclusions

1. The outcome of the final felling sawlog for Scot pine, Norway spruce and birch differ regionally in Latvia. The smallest regional difference of sawlog outcome was found for spruce (9.4%), slightly larger for pine (10.5%) and the largest for birch (16.2%).
2. Three regions with different sawlog outcome were found for Scot pine, six for Norway spruce and seven for birch in Latvia. Several spruces and birch regions have similar sawlog outcome, but those do not have borders. They are between regions with higher or lower sawlog outcome. For all species neighbouring sawlog outcome in regions differ for at least 4 – 5%.

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References

1. Baumanis I., Gailis A., Liepiņš K. (2001) Latvijas priežu provinienču salīdzinājums (Comparison of Scots pine provenances in Latvia). *Mežzinātne*, 46, 52 – 66. lpp. (in Latvian).
2. Dubrovskis D., Sarmulis Z., Daģis S., Zīmelis A., Šmits I., Krūmiņš M., Baltmanis R. (2013) Koku stumbra formas veidules un sortimentu iznākuma prognožu noteikšana. Zinātniskā pētījuma starpatskaite (Projection of tree stems surface form and round wood assortments outcome. Overview of research). Available at: www.lvm.lv/files/text/Veidule_Sortimentu_Prognozes_4starpatskaite_MF_2013.pdf, 25 February 2014. (in Latvian).
3. Lībiete Z. (2006) Pētījums par priedes, bērza un egles audžu ražības un stumbra kvalitātes reģionālajām atšķirībām Latvijā uz meža statistiskās inventarizācijas parauglaukumu bāzes. Pārskats par Meža attīstības fonda pasūtīto pētījumu (A study of regional differences of pine, birch and spruce stands productions and stem quality in Latvia based on National forest inventory sample plots. Overview of Forest development fund financed research). Latvian State Forest Research Institute 'Silava', Salaspils, 45 lpp. (in Latvian).
4. Neimane U. (2009a) Geographical differences in growth and quality characters of scots pine Latvian populations. In: Gaile Z., Zvirbule-Bērziņa A., Assouline G., Špoģis K., Ciproviča I., Kaķītis A., Dumbrauskas A. (eds), Research for Rural Development 2009, *Annual 15th International Scientific Conference Proceedings*, Latvia University of Agriculture, Jelgava, Latvia, pp. 135 – 142.
5. Neimane U., Veinberga I., Ruņģis D. (2009b) Parastās priedes populāciju ģeogrāfisko atšķirību fenotipiskās un ģenētiskās īpašības Latvijas teritorijā (Phenotypic and genetic aspects of geographical differences in Scots pine populations of Latvia). *Mežzinātne*, 53, 3 – 15.lpp. (in Latvian).
6. Špalte E., Zālītis P. (2003) Latvijas egļu audžu kvalitāte ciršanas vecumā (The quality of spruce stands in Latvia at the felling age). *Mežzinātne*, 46, 3 – 20. lpp. (in Latvian).
7. Zālītis P., Špalte E. (1998) Latvijas priežu audžu kvalitāte ciršanas vecumā (Standing volume and stemwood quality spruce at the cutting age). *Mežzinātne*, 41, 128 – 143. lpp. (in Latvian).
8. Zālītis P., Špalte E. (2000) Priežu kokaudžu krāja un stumbra koksnes kvalitāte ciršanas vecumā (Standing volume and steamwood quality of pine at the cuttinga age). *Mežzinātne*, 43, 11 – 28. lpp. (in Latvian).
9. Zālītis P., Špalte E., Liepiņš K. (2002) Augstvērtīgu bērzu audžu diagnostika, ģenētisko un ekoloģisko faktoru, kā arī mežsaimniecisko pasākumu ietekmes noteikšana pēc bērzu stumbru kvalitātes rādītājiem (Diagnostics of high quality birch stands, determination of impact of genetic and ecological factors and silvicultural activities on birch steamwood quality). *Mežzinātne*, 45, 17 – 45. lpp. (in Latvian).
10. Zālītis T. (2008) Kārpainā bērza (*Betula pendula* Roth.) augšanas gaitu un stumbra kvalitāti ietekmējošie faktori auglīgajos meža tipos Latvijā. Promocijas darba kopsavilkums. (The factors influencing the growth and stem quality of Silver birch (*Betula pendula* Roth.) stands on fertile site types in Latvia. Resume of the PhD paper). Latvijas Lauksaimniecības universitāte, Jelgava, 50. lpp. (in Latvian).

PRODUCTIVITY OF HARVESTERS IN COMMERCIAL THINNINGS IN THE FOREST STANDS OF DIFFERENT COMPOSITION OF SPECIES

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Abstract
The aim of the study is to ascertain how different compositions of stand species affect the work of the harvester in commercial thinning under Latvia's conditions. The data of the harvester – time-tracking files (*.drf) have been used as a basis for the study, where productivity is expressed as the prepared amount of round timber in cubic meters in a unit of time – an hour (m^3 h^{-1}). The data were collected from 100 commercial thinning areas which were divided into three types depending on the composition of the species: pure pine stands, pure spruce stands and deciduous tree mixed stands (mixed with coniferous trees). All the data for the study were collected in the forests managed by JSC 'Latvia`s State Forests'. By summarizing the data, it has been established that in pure pine stands the average volume of the stem to be removed is 0.092 m^3, in mixed stands – 0.085 m^3 and in pure spruce stands - 0.068 m^3. The research demonstrates that the harvester showed its highest productivity while working in pure pine stands – 3.96 m^3 h^{-1}, the second best result was achieved in the mixed stands – 3.67 m^3 h^{-1}, but the lowest rate was demonstrated in pure spruce stands – 3.09 m^3 h^{-1}. Significant differences were observed in the productivity of the harvester between pure pine and pure spruce stands. Comparing the calculations of standard deviations in the harvester productivity, it can be seen that they are the biggest in mixed stands, while the lowest rate is demonstrated in pure spruce stands.
Key words: thinning, harvester productivity, different composition of species.

Introduction

Forestry plays as important a role in Latvia's economy as other business sectors do, thus, one of its objectives is to produce high quality wood at the lowest possible costs in compliance with Latvian rules and regulations. In parallel with the introduction of machine operated processes in logging, this research into the productivity of logging machines is being carried out. If in final fellings the machine operated technologies are an effective and quick solution to deal with trees that are planned to be cut and moved in difficult driving conditions, in commercial thinnings a significant aspect emerges – after felling the residual stand should be healthy and perspective, excluding the damages of remaining tree roots and surface parts, thus reaching the optimum of the target stand (Розинь, 1978; Савельев, 1989).

Regardless of the afore mentioned, one of the most important economic characteristics also in machine operated logging is harvester work productivity. According to the definition, the work productivity is a parameter showing the amount of products produced in a given amount of time. The productivity of a harvester is generally measured as the amount of the product – roundwood processed in an hour (m^3 h^{-1}).

The work productivity of a harvester in commercial thinnings is influenced by various factors. Summarizing the findings of several forestry scientists, these factors can be divided into 3 big groups:

1) forestry factors;
2) technical factors;
3) operator's factors.

It can be concluded from the afore mentioned that the productivity of a harvester in commercial thinnings is a complicated multifactor parameter. Most of the research pertaining to the use of machinery in timber harvesting shows that the forestry factors which are influential are mainly derived from the parameters of forest stand evaluation:

- average volume of the stem of the tree to be cut;
- composition of tree species in the stand;
- stand density;
- type of forest growth conditions (gound stability, mutual location of trees);
- shape of the tree stem to be cut.

Most thoroughly the relationship between the average stem volume of the trees to be cut and logging productivity has been analysed. The parameters of work productivity for practically all the machinery used in logging correlate closely with the average volume of the tree stem (m^3). This relationship was also studied by a group of scientists from the Latvian State Forest Research Institute 'Silava', stating that with an increase in the average volume of the tree stem, the productivity of the harvester increases. This relationship has also been proved by a lot of research in Nordic countries (Brunberg, 1997; Brunberg et al., 2007; Eliasson, 1998; Lageson, 1997; Siren and Aaltio, 2003), and in North America (Kellog and Bettinger, 1994; Landford and Stokes, 1995, 1996; Pulkki, 2003). Modern harvesters are so efficient that processing of a big tree takes a little longer time than processing of a small sized tree. That inevitably leads to the increase in work productivity, although the relationship is not linear. At a definite stem volume the work productivity of the respective harvester starts decreasing again (Lageson, 1997). At this moment

the tree dimensions are too big for a definite logging machine.

The tree species as a factor influencing the productivity of a harvester in commercial thinnings has been studied only partly. Some specialists acknowledge that the work in coniferous stands presents fewer problems than that in deciduous and mixed composition stands. Thus, it has been acknowledged that the harvester productivity in coniferous stands is higher than under similar conditions in deciduous stands. For commercial thinnings it is important to establish a target stand model which would depend on the composition of species in the stand. The more complicated the composition of tree species in the stand before thinning, the faster the decline in the productivity of the machinery used, when compared to pure stands (Uusitalo, 2004).

Taking into consideration the above mentioned, the aim of the research was set: to compare the harvester's work productivity in commercial thinnings in the stands of different composition of tree species.

Materials and Methods

Harvester productivity depending on the characteristics of the stand was analysed using harvester's operation time recording files – (*.drf). They were automatically created and accummulated in each harvester's computer individually for each fellig site, and they store information on the active operation time and idle time, and also the information about the average volume of roundwood in m³ has been processed in a certain unit of time – in an hour (m^3 h^{-1}) in each felling site, distributed per operator, etc.

For this research the harvester's operation time recording files were obtained from the data archive servers of JSC 'Latvijas valsts meži'. At first, the machine thinned stands were selected and assessed from the data base. To exclude the regional, operator's harvesting companies and harvester's characteristics, the harvested stands were selected uniformely located over the entire territory of Latvia. It was assumed that in this research it was necessary to analyse the productivity of work by using the data from about 100 commercial thinning sites. These thinned stands were selected so that their area would not be smaller than 2.0 ha. Afterwards, these machine operated thinned stands were divided according to their composition of species. The commercial thinning areas in which, according to the distribution by compartments, the dominant species and forest types differed, were excluded (wet and swamp forest types).

In the researched sites the three most popular commercial thinning harvester make and models used in Latvia were: JohnDeere 1070, Ponsse Beaver and Valmet 901.4. The information about the researched felling sites is summarised in Table 1.

Table 1

Characteristics of thinning sites

Forest district	Forest block	Compartment (s)	Area, ha	Species composition	Harvester brand, model
Aknīstes	37	12;15	7.7	9E1B	John Deere 1070
Žīguru	437	15	4.9	9E1B	John Deere 1070
Krīvukalna	410	28	2	10E	John Deere 1070
Misas	345	11	5.2	9E1B	Ponsse Beaver
Aknīstes	246	1	3.1	9E1B	Valmet 901.4
Zilokalnu	194	20;26	4.7	9E1B	John Deere 1070
Pededzes	522	6;9;10	6.3	9E1B	John Deere 1070
Madonas	4	4;5;7;8	3.5	9E1B	Valmet 901.4
Limbažu	45	4;5	3.4	9E1B	John Deere 1070
Aknīstes	242	16	4.7	10E	Valmet 901.4
Lubānas	322	18	3	9E1B	John Deere 1070
Piebalgas	259	13;22	3.7	9E1B	John Deere 1070
Vecumnieku	299	8	2.1	10E	John Deere 1070
Ludzas	196	2;13;18;22	9.5	10E	John Deere 1070
Lejasciema	445	8	2.1	9E1B	John Deere 1070
Apriķu	203	17	3.1	9E1B	John Deere 1070
Madonas	310	15	2.5	9E1B	Valmet 901.4
Limbažu	134	2;3	2.1	9E1B	John Deere 1070
Silvas	257	2	2.3	9E1B	John Deere 1070

Forest district	Forest block	Compartment (s)	Area, ha	Species composition	Harvester brand, model
Žīguru	315	9;10;12	10.3	9E1B	John Deere 1070
Mālupes	236	8	2.1	10E	John Deere 1070
Pededzes	525	15	4.7	9E1B	John Deere 1070
Aknīstes	13	15	3	9E1B	Valmet 901.4
Skaistkalnes	373	4	3.7	9E1B	John Deere 1070
Pededzes	150	6;7;8;9	9	10E	John Deere 1070
Piejūras	344	9;14;15	10	9E1B	John Deere 1070
Salacgrīvas	153	1	2.1	9E1B	John Deere 1070
Ogres	240	14;17	8	10E	John Deere 1070
Krīvukalna	410	26	3.7	10E	John Deere 1070
Aknīstes	248	18;19	6.7	10E	Valmet 901.4
Lejasciema	443	15;16	3	9E1B	John Deere 1070
Valmieras	38	5;9	16.3	10E	John Deere 1070
Pededzes	482	5;7	2.2	9E1B	John Deere 1070
Sikšņu	209	7	2.4	10E	John Deere 1070
Rēzeknes	100	7;8;9;10	16.7	5B2M2E1A	Ponsse Beaver
Melnupes	146	7;18	4.6	3Os3E2B1Ba1A	John Deere 1070
Engures	151	12;22	2.5	6B2E2L	Ponsse Beaver
Mālupes	434	3	2.1	5B3A2E	John Deere 1070
Krīvukalna	270	17	4.3	5A4B1Ba	John Deere 1070
Vēru	208	9;10;11;12	8.5	6B2P1E1Ba	John Deere 1070
Rendas	336	1;5;6;13;20	6.7	6B2M1P1E	Ponsse Beaver
Balvu	44	2	7.7	5B4A1E	John Deere 1070
Ābeļu	106	3;4	6.8	6B3A1E	John Deere 1070
Balvu	57	9;10;17	10	5B4A2E	John Deere 1070
Pededzes	215	1	12.9	6B2E1A	John Deere 1070
Rūjienas	285	1;3;5;6	5.8	3Ba3E3B1A	John Deere 1070
Lubānas	582	2;7	5.5	5A3Ba2B	Valmet 901.4
Venemas	230	16	2	6B2E1M1A	John Deere 1070
Limbažu	308	12	5.9	4B3Ba2M1E	John Deere 1070
Pededzes	181	1;2;5	9.6	5B3L2M	John Deere 1070
Rendas	422	20;21	2.2	5B3M1Ba	Ponsse Beaver
Lejasciema	315	14;15;16;17;23	8.6	6B2E1M1A	John Deere 1070
Balvu	160	2;6;8;9;13	6.4	4B2P2A1E1M	John Deere 1070
Limbažu	467	5	2.5	3Ba3M2E1B1Os	John Deere 1070
Sikšņu	29	1;2	5.8	5A4B1W	John Deere 1070
Ābeļu	161	5;6	10.8	4B3A3E	John Deere 1070
Mālupes	415	22;23;24;29;30	11.6	4B2A2M1E1P	John Deere 1070
Engures	147	14;15;16	1.8	3A3B3P1E	Ponsse Beaver
Rendas	425	2	5.4	6B2A1E1P	Ponsse Beaver
Limbažu	144	13	5.6	4B2M2E2A	John Deere 1070
Lejasciema	440	25;28;29	2.7	4B3A2P1E	John Deere 1070
Ropažu	309	3;4	6.6	6B2M1A1E	John Deere 1070
Kokneses	232	1;3;7;8;12	11.4	6B3E1M	John Deere 1070
Mālupes	156	4	2.5	5B4A2L	John Deere 1070
Sventenes	36	13;14	5.3	6B2E2P1M	John Deere 1070
Ogres	185	5	2.8	3L3A2Ba2B	John Deere 1070
Kokneses	200	19;21	2.1	6B3E1M	John Deere 1070
Lejasciema	116	4;5;11	6.8	4A4B2E	Ponsse Beaver
Ventas	376	2;3;4;5;6;7;8;9;	8.4	9P1E	Ponsse Beaver
Ventas	374	1;2;3;4;5;6;10;11	18.5	9P1E	John Deere 1070

Forest district	Forest block	Compartment (s)	Area, ha	Species composition	Harvester brand, model
Silvas	20	3;10	8.4	9P1E	John Deere 1070
Skaistkalnes	203	3;8	2.4	9P1E	Ponsse Beaver
Engures	92	22	4.5	10P	John Deere 1070
Jaunjelgavas	61	14;15	2.8	9P1B	Ponsse Beaver
Ventas	31	17;18;30	4.3	9P1B	Ponsse Beaver
Usmas	129	1;2	2.8	9P1E	John Deere 1070
Lejasciema	198	21;30;31;32;34;35	5.4	9P1E	John Deere 1070
Rendas	415	5;6;7;	6.8	10P	John Deere 1070
Grobiņas	502	1	2.7	9P1B	John Deere 1070
Strenču	449	8;16;17;18;19	9.2	9P1B	Ponsse Beaver
Ventas	209	11;13	3.7	10P	John Deere 1070
Lejasciema	88	34	4.3	9P1E	John Deere 1070
Lubānas	171	1	3.1	9P1B	Ponsse Beaver
Rendas	415	12;14;16	4.8	9P1E	John Deere 1070
Alsungas	141	5	2.5	9P1E	John Deere 1070
Sikšņu	197	8	2.2	9P1E	John Deere 1070
Balvu	78	17;18;19	6.2	10P	John Deere 1070
Jaunjelgavas	41	10;12	8.7	9P1B	John Deere 1070
Pededzes	608	2;12;13;15;16	7.5	9P1E	Ponsse Beaver
Rendas	478	19	2.1	9P1E	John Deere 1070
Grīņu	457	15;22	2.8	9P1E	John Deere 1070
Alsungas	382	7;9	2	9P1E	Valmet 901.4
Balvu	11	28	4.4	9P1B	John Deere 1070
Ērģemes	49	13	3.8	9P1E	John Deere 1070
Ugāles	59	2	5.3	9P1E	Ponsse Beaver
Jaunjelgavas	161	2;3;4	2.1	9P1E	John Deere 1070
Ventas	48	28	2.9	9P1E	Ponsse Beaver
Alsungas	132	4;5;7	6.9	9P1E	Ponsse Beaver
Birzgales	48	4	5.9	9P1E	John Deere 1070
Ventas	66	35	3.4	9P1E	John Deere 1070
Bauskas	46	2	9.8	9P1E	John Deere 1070
Krāslavas	254	1	5.5	9P1B	John Deere 1070
Ventas	370	13;14;15;16	4.4	9P1E	Ponsse Beaver

Explanations: P – pine, E – spruce, B – birch, A – aspen, L - lime, M – black alder, Ba – grey alder. As the number of limiting criteria is big, the selected felling sites were divided in three types by the composition of species:

1) pure pine stands (dominant species – pine making up at least 80%);
2) pure spruce stands (dominant species – spruce making up at least 80%);
3) mixed deciduous stands (dominant species – deciduous trees making up 51 – 70%).

Afterwards, harvester operation time recording files were found for the selected felling sites. These files were opened using the software programme 'Silvia'. The information obtained from these files was summarized, using the average harvester productivity of the felling sites (m^3 h^{-1}) and the average volume of the tree stems (m^3) to be removed as the basis, not taking into consideration the idle time of the harvester, distribution by operators, etc. Then the data were entered into the software programme SPSS 17 where they were statistically processed.

For statistical processing the one-way Anova analysis and the T-test were used. The Anova analysis was used to find whether the difference in harvester productivity with regard to the composition of species in the stand is or is not significant. The T-test was used to calculate the credibility interval and to show it in a graphical way.

Results and Discussion

The results of the Anova analysis are summarized in Table 2.

Table 2

The comparison of the productivity of a harvester (m^3 h^{-1}) in stands of different composition (Anova analysis)

Groups	Count	Sum	Average	Variance	Std. Deviations
Pure pine stands	33	134.57	3.958	1565	1.25081
Pure spruce stands	33	10512	3.092	0.834	0.91345
Mixed deciduous stands	33	124.88	3.673	2.235	1.49515

Source of Variations	SS	df	MS	F	P-value	F crit
Between Groups	13.252	2	6.626	4.289	0.016	3.088
Within Groups	152.935	99	1.545			
Total	166.187	101				

Table 3

Harvester productivity (m^3 h^{-1}) comparison in stands of different composition (T-test)

Type of Stand	t	df	Average	95% confidence interval	
				highest	lowest
Pure pine stands	18.451	33	3.95794	3.5215	4.3944
Pure spruce stands	19.736	33	3.09176	2.7730	3.4105
Mixed deciduous stands	14.324	33	3.67294	3.1513	4.1946

By comparing the standard deviations in Table 2, it is evident that they are the highest in deciduous mixed forest stands. It means that when thinning different deciduous mixed stands, the parameters of the harvester productivity can be within a wide range, whereas in pure spruce stands the standard deviations are the smallest. It could be difficult for the loggers to predict how productive the work will be in each felling site of a mixed stand, whereas in pure spruce stands there should be no great surprises in this respect.

Viewing the second part of Table 2, it can be seen that the actual Fischer's value is greater than the critical Fischer's value ($F = 4.289 > Fcrit = 3.088$). That means that the zero hypothesis can be rejected with a 95% possibility that the harvester's productivity is identical in all groups of forest stands. The same can be concluded when observing the P-value $0.016 < 0.05$, thus we reject the zero hypothesis with the probability of 95%.

Comparing the grading classes, it was stated that there were significant differences in harvester's productivity between pure pine and pure spruce stands (Table 2). In Figure 1, the credibility intervals calculated by the T- test can also be seen. The credibility interval of mixed deciduous stands coincides with that of pure spruce and pine stands, which means that when the harvester operates in mixed deciduous stands, its productivity does not differ significantly from the productivity in pure coniferous stands.

Figure 1 shows that the highest harvester productivity is in pure pine stands, the second highest is for the harvester operating in mixed deciduous stands, but the lowest – in pure spruce stands.

A peculiar situation in Latvian state forests can be observed with regard to deciduous tree stands. In Latvia, there are comparatively few deciduous trees in pure stands of average age. They are mostly mixed stands of different combinations. These mixed stands are often located in wet areas, in fertile soils with a great diversity of species. The situation with pure coniferous stands in Latvia's forests is as interesting as with deciduous stands. They have a specific historical origin, development and age structure. Today the pure spruce stands of Latvia which are to be commercially thinned are the artificially regenerated stands of the 70s and 80s of the last century. The ensured planting intensity there was 8 – 10 thousand plants per hectare. Commercial thinning of young stands was also not carried out intensively enough, since the goal at that time was to grow dense spruce stands (Epalts, 2005).

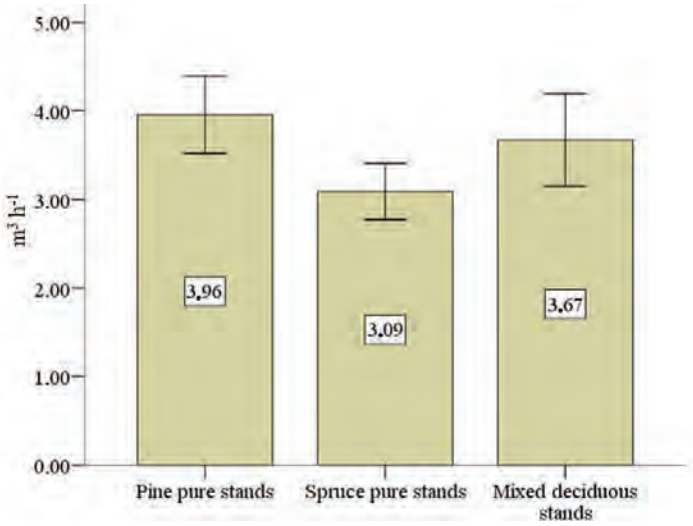

Figure 1. Harvester productivity depending on the composition of the stand's species.

Thus, when the stands reach the age when commercial thinning is to be carried out, they in most cases are very dense. It influences the harvester productivity in Latvia's conditions comparing spruce stands with pine and deciduous tree stands.

The forest type as a factor influencing the productivity of logging machines is most often associated with the bearing capacity of the soil. Some authors (Epalts, 2002) consider that this factor can significantly influence the productivity of the machinery; however, it largerly depends on the season and climatic conditions; thus, this factor will not always be significant. The shape of the tree stem also significantly influences the productivity of the machinery, but there is no uniformed conclusion on that. Several researches acknowledge that the shape of the stem influences debranching and the end result of the assortments of the commercial timber (Uusitalo, 2004). In this research when selecting data from 100 felling sites, which are uniformly scattered throughout the entire territory of Latvia, the peculiarities of the shapes of tree stem should not influence the results of the research.

Some researchers record the density of the stand (the number of trees per ha) before and after carrying out the commercial thinning as a significant forestry factor influencing the productivity of machinery, but this factor is closely associated with technical specifications of the machinery used - the size of the machine, linear sizes of operational units, etc. (Савельев, 1989). The influence of these factors has not yet been fully researched and the influence should not be present on the results of this research, since similar thinning harvesters with almost identical parameters were used in this research.

Conclusions

1. The highest harvester productivity implementing commercial thinning was recorded in pure pine stands – 3.96 m^3 h^{-1} at the average removable tree stem volume of 0.092 m^3. The second highest work productivity was recorded in mixed species stands – 3.67 m^3 h^{-1} at the average removable stem volume of 0.085 m^3 and the lowest – in pure spruce stands – 3.09 m^3 h^{-1} at the average removable stem volume of 0.068 m^3.
2. Comparing the grading classes, significant diferences in harvester productivity were found between pure pine and pure spruce stands.
3. The credibility interval of mixed deciduous tree stands coincides with the credibility interval of pure spruce and pine stands, which means that when the harvester operates in mixed deciduous tree stands, its productivity does not significantly differ from that in pure coniferous stands.
4. Comparing the calculated standard deviations of harvester productivity, it is envident that they are the greatest in mixed stands, but the smallest ones in pure spruce stands. It means that the parameters of harvester productivity, when commercial thinning is carried out, can be in a wide range and it could be difficult for forest harvesting professionals to predict how productive the work will be in each felling site of the mixed stand, whereas the parameters of harvester productivity in pure spruce stands are in a narrower range.

References

1. Brunberg T. (1997) *Basic productivity norms for single-grip harvesters in thinning* The Forestry Research Institute of Sweden, Uppsala, 118 p.

2. Brunberg T., Thor M., Norin K. (2007*) Logging productivity and price models in Sweden and Latvia*. AS Latvijas valsts meži, Riga, 16 p.
3. Eliasson L. (1998) *Analyses of single-grip harvester productivity* Doctoral thesis, Swedish University of Agricultural Sciences, Department of Operational Efficiency, Umea. 24 p.
4. Epalts A. (2002) Mehanizētas sastāva kopšanas cirtes ietekme uz priežu audzes attīstību (Impact on the development of pine stands after mechanized thinning). *LLU raksti*, Nr. 5, 53 – 58 lpp. (in Latvian).
5. Epalts A. (2005) Mehanizētās krājas kopšanas cirtes ietekme uz egļu audzes attīstību (Impact on the development of spruce stands after mechanized thinning). *LLU raksti*, Nr. 14 (309), 94 – 99 lpp. (in Latvian).
6. Kellogg L.D., Bettinger P. (1994) Thinning productivity and cost for mechanized cut-to-length system in the Northwest pacific coast region of the USA. *Journal of Forest Engineering, 5(2),* pp. 43 – 54.
7. Lageson H. (1997) Effects of thinning type on the harvester productivity and on the residual stand. *Journal of Forest Engineering,* 8(2), pp. 7 – 14.
8. Landford B.J., Stokes B.J. (1995) Comparison of two thinning systems. Part I. Stand and site impacts. *Forest Products Journal,* 45 (5), pp. 74 – 79.
9. Landford B.J., Stokes B.J. (1996) Comparison of two thinning systems. Part II. Productivity and costs. *Forest Products Journal,* 46 (11/12), pp. 47 – 53.
10. Pulkki R. (2003) *Minimizing negative environmental impacts of forest harvesting operations.* Towards sustainable management of the boreal forest, NRC Research Press, Ottawa, Ontario, Canada, pp. 581 – 628.
11. Siren M., Aaltio H. (2003) Productivity and costs of thinning harvesters and harwarders. *Journal of Forest Engineering*, 14 (1), pp. 39 – 48.
12. Uusitalo J. (2004) Heartwood and extractive content of Scots pine in southern Finland: models to apply at harvest. *Wood and Fibre Science,* 36(1), pp. 3 – 8.
13. Розинь Т. (1978) Исследование цикла машинного выноса деревьев при рубке леса выборным способом (Research of machine removal tree cycle in selective felling). *Автореферат диссертации*, Минск, 26 с. (in Russian).
14. Савельев А. (1989) Разработка технологии рубок ухода на основе исследования доступности деревьев при машинном способе заготовки (Development of technology for thinning on the basis of research in machine availability tree of harvesting method). *Автореферат диссертации*, Минск, 27 с. (in Russian).

IMPACT OF ASSORTIMENTS' STRUCTURE ON HARVESTING PRODUCTIVITY AND COSTS OF PRE-COMMERCIAL THINNING

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Abstract
The study aims to find productivity of biofuel production in pre-commercial thinning, depending on the structure of assortments and to identify factors that influence the cost of mechanized tending of young stands. Five work methods were compared in the study, starting from standard thinning (production of sawn timber, pulpwood and firewood) with no use of accumulating device and finalizing with the biofuel method – no other assortments except biofuel are produced and the most intense use of accumulating device is considered. Accumulating device is not used for production of standard round-wood assortments. The experiments were implemented in February – March, 2013. The material produced in the study was used by 'Graanul Pellets' company to evaluate possibilities to use timber extracted in pre-commercial thinning of coniferous stands in production of premium class pellets. The average productivity in different stands is statistically different. The study shows that productivity of harvesting is 3.7 … 5.1 m^3 h^{-1}, which can be increased by more intensive use of accumulation. No difference found between work methods in forwarding trials, but productivity grows with increase of share of firewood. Average loading time 26 min, unloading 3.6 min, average load 6.0 m^3. Prime-cost calculation shows that harvesting costs depending on the working method is in the range of 22.4 … 26.5 EUR m^{-3}. Comparison of potential expenses and incomes demonstrates that economically the most efficient is production of traditional assortments (sawn wood, small size sawn wood, pulp wood and firewood) with an active use of accumulating function.
Key words: biofuel, work methods, young stands.

Introduction

Yong stand tending or per-commercial thinning is a measure required in forestry. It is performed mainly with manual cutting without collecting of small diameter wood (Lazdāns, 2006; Meža enciklopēdija, 2003). Studies of efficiency of young stand tending technologies in 2012 showed that the young stand manual cutting still is the most cost-efficient way of young stand tending, followed by young stand tending with harvester equipped with special additional accumulating device for head (Lazdiņš et al., 2012). However, with growing demand for biofuel, the mechanized tending of young stands becomes an urgent issue. It is possible to perform qualitative young stand tending by using harvesters and produce round-wood assortments and biofuel.

Technology of young stand tending can be divided into four groups: harvesting with a harvester, with a harwarder, combined harvesting and chipping equipments, or manual cutting (Lazdiņš, 2013c). Studies on the young stand tending in Scandinavia and Latvia confirm, that mostly medium-sized harvesters with accumulating device are suitable for young stand tending (Lazdāns et al., 2008; Sirén and Aaltio, 2003). A head with an accumulating device allows multiple gripping of trees and cutting (Lazdiņš, 2013c). Such harvesters are maneuverable in young stands and are suitable for cutting and processing of small diameter trees.

Studies of usage of the mid-class harvesters in mechanized tending of young stands are carried out by Joint Stock Company 'Latvia's State Forests' commissioned project 'Industrial research of renewable energy production, processing and logistics'.

The study evaluated the impact of the structure of assortment gained by young stand tending on productivity and costs (Kalēja et al., 2014; Lazdiņš, 2013a; Lazdiņš, 2013b; Lazdiņš, 2013c). In addition to the traditional round timber assortment groups (sawn timber, pulpwood and firewood), an assortment of biofuel can be prepared from treetops and trunks that couldn't be used for traditional assortment (Lazdiņš, 2013c).

Studies in Latvian and Scandinavian countries have shown that the usage of accumulating device for preparation of non-traditional assortment greatly increases productivity and reduces the cost of mechanized tending of young stands (Lazdiņš, 2013a; Lazdiņš, 2013c; Sirena and Aaltio, 2003). Assuming that an average distance of forwarding is constant, the main factors affecting the productivity are average tree size of the stand, removal per hectare and number of timber assortments (Sirena and Aaltio, 2003). The structure of produced assortment, in turn, is determined by the chosen method of working. The studies confirmed the hypothesis that the highest productivity (amount of trees that are harvested in certain amount of time) of each machine could be achieved by reducing modifications of produced assortment (Lazdiņš, 2013c).

Studies of deciduous stands show that the cost of manual tending of young stands in harsh conditions, depending on tree's dimensions and tree stands thickness, ranges from 343 EUR ha^{-1} to 488 EUR ha^{-1}. Actual costs are up to 3 times smaller, as service providers have to tend a variety of stands, including those where the cost of 1 ha is significantly below average (Lazdiņš, 2013b). Costs of mechanic young stand tending, depending on the harvester's type, ranged on average from 800 EUR ha^{-1} to 1 113 EUR ha^{-1} (Lazdiņš, 2013b; Lazdiņš, 2013c). Although mechanized tending of young stands requires a significantly higher cost, realization of produced assortment provides some revenue. Earnings are determined by current market situation as well as the chosen supply chain model (Laina et al., 2013; Lazdiņš, 2013c; Walsh and Strandgard, 2014). The aim of the study was to find productivity of biofuel production in pre-commercial thinning, depending on the structure of assortments and to identify factors that influence the cost of mechanized tending of young stands.

Materials and Methods

The study was implemented in 4 coniferous stands representing fertile *Myrtillosa* and *Hylocomiosa* site types in the central part of Latvia nearby Koknese. The stands were specially selected for proper density (at least 1500 trees per ha^{-1}) and dimensions of trees (height of trees 9 … 12 m). The experiments (harvesting and forwarding operations) were implemented in February – March, 2013. The average temperature during the study was 1.6 degrees lower than the temperature in the given historical period. The strip-roads were marked before thinning at 20 m distance between each other. The main characteristics of stands are provided in Table 1.

For production of different assortments (work methods 1 … 4) stands 503-479-12 and 503-481-6 were selected and biofuel method (work method 5) was implemented in stands 503-455-13 and 503-455-14. Biomass expansion factors elaborated for afforested lands are borrowed for calculations (Lazdiņš, 2011d). Five work methods were compared in the study:

1. Production of traditional assortments (sawn wood 14 X 18 mm, small size sawn wood 10 X 14 mm, pulp wood and firewood), min. diameter of firewood at top 50 mm, residues left in stand, accumulating function is not used.
2. Production of traditional assortments (sawn wood, small size sawn wood, pulp wood and firewood), min. diameter of firewood at top 30 mm, residues left in stand, active use of accumulating function.
3. Production of limited number of assortments (sawn wood, small size sawn wood and firewood), min. diameter of firewood at top 30 mm, residues left in stand, active use of accumulating function.
4. Production of limited number of assortments (sawn wood and firewood), min. diameter of firewood at top 30 mm, residues left in stand, active use of accumulating function.
5. Production of firewood with min. diameter at top 30 mm, residues left in stand, active use of accumulating function.

John Deere 1070 E with H754 head equipped with special additional holders and boom length 10 m was used in the study. Two experienced operators drove the machine; however, none of the operators had previous experience with small dimension biofuel assortments and accumulating felling heads.

Standard Timberjack 810B forwarder was used in the study. All loads were weighed during forwarding, and after each fifth load or after changing position of scales empty loads were weighed.

The material with a truck was delivered to LLC 'Graanul Pellets' storage yard using standard 68 m^3 truck Delivery distance 150 km in one direction.

The material (biofuel assortment as well as sawn timber and pulp-wood produced in trials) was chipped with stationary chipper Jenz HE 700 after debarking in LLC 'Graanul Pellets' storage yard. Proportion of bark according to information provided by LLC 'Graanul Pellets' was 10% by mass (naturally wet). In order to perform recalculation to dry matter tons,

Table 1

Characteristic of stands

Object code	Area, ha	Dominant species	Average diameter of trees, cm	Average height of trees, m	Average basal area, m^3 ha^{-1}
503-455-13	3.6	spruce (*Picea abies*)	9.7	7.7	12.1
503-455-14	4.3	spruce (*Picea abies*)	9.6	9.2	19.3
503-479-12	2.4	pine (*Pinus sylvestris*)	12.0	11.7	29.5
503-481-6	1.2	spruce (*Picea abies*)	8.2	10.0	13.1

a conversion factor (1 ton of naturally wet material (average moisture content 60%) corresponds to 0.4 dry tons) was used.

Prim-cost calculation and potential income and expenses of mechanized young stand tending calculations are done according to calculation models that are used in similar studies carried out previously (Lazdiņš[c], 2013).

To determine the level of significance of data, the t-test is used.

Results and Discussion

Basal area before thinning on average in all stands was 18 m^2 ha^{-1}; the average number of trees 2360 per ha^{-1}; diameter 10 cm; tree height 10 m; growing stock 62 m^3 ha^{-1}. After thinning the average basal area reduced to 13 m^2 h^{-1}; number of trees – to 1154 per ha^{-1}; diameter of trees increased to 12 cm. Proportion of extracted trees is 26 … 61% from initial number of trees. In 3 of 4 objects the number of extracted trees exceeds permitted value by 9 … 21% (if the area of strip-roads is considered). If the area of strip-roads (20%) is not considered, intensity of thinning could be increased.

The distribution of trees after thinning is even (Figure 1).

In total, 10722 trees were extracted in the experiment. Extracted biomass according to weighing of forwarder and analyses of moisture of fresh wood was 133 tons of dry matter (60 MWh ha^{-1} of primary energy); harvested stock with bark – 351 m^3 (31 m^3 ha^{-1} or 152 LV m^3 ha^{-1} of chips). According to round-wood measured data, the amount of delivered wood was 316 m^3 under-bark (about 354 m^3 with bark) or about 147 tons of dry mass. The study approved that harvester measurement data cannot be used to account the amount of biomass produced by simultaneous extraction of multiple trees, because they are considerably underestimating the amount of produced material. The volume of average extracted tree is 0.03 m^3; the diameter of average extracted tree – 10 cm; the average number of trees per cycle – 1.3 pieces (max. 8 … 10 trees per cycle, in firewood method – 1.4 trees per cycle). On average, 30 trees have to be processed to produce 1 m^3 of round-wood assortments.

The average distribution of productive work time in all work methods is shown in Figure 2. Bucking is the most time consuming work element (28%), the second is reaching tree (24%). Both work elements can be considerably reduced, if accumulating function is used more often, respectively.

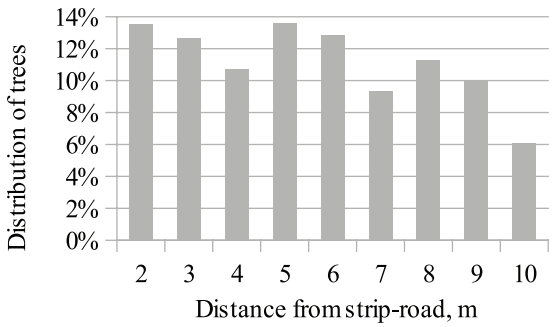

Figure 1. Distance of remaining trees from center of strip-road.

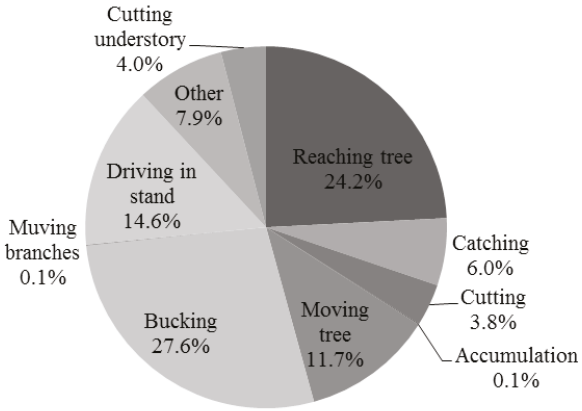

Figure 2. Average distribution of work elements in harvesting.

The production of less assortments reduces bucking time, and this value correlates with the number of crane cycles with more than one tree. In work method 4 the duration of bucking is twice less than in work method 1. This means that broader use of accumulating function may increase productivity considerably. In stands for biofuel (only) production average productivity was:

- 503-455-13 – 4.5 m^3 or 151 trees per productive hour;
- 503-455-14 – 5.0 m^3 or 159 trees per productive hour;

In stands used for comparison of impact of assortments' structure average productivity was:

- 503-479-12 – 5.0 m^3 or 133 trees per productive hour;
- 503-481-6 – 4.4 m^3 or 137 trees per productive hour.

Average productivity in all stands was 4.9 m^3 or 148 trees per productive hour. The provided productive figures exclude driving in and out of the stand.

Comparison of work methods demonstrates an increase of productivity of harvesting with reduction of the number of assortments, except work method 5, where the average diameter of trees was considerably smaller than in other stands. The productivity figures for different methods are:

1. work method – 4.7 m^3 or 114 trees per productive hour;
2. work method – 5.1 m^3 or 126 trees per productive hour;
3. work method – 5.0 m^3 or 141 trees per productive hour;
4. work method – 5.7 m^3 or 156 trees per productive hour;
5. work method – 3.7 m^3 or 136 trees per productive hour.

Production of biofuel assortments from pulp-wood and small dimensions saw logs increase harvesting productivity significantly. The study approves that the potential of accumulating device is not fully utilized.

In total, 58 loads were extracted, the average load of 2.3 tons dry mass or 6.1 m^3. Weight of pure biofuel loads equals to the weight of average load – 2.3 tons of dry mass or 6.0 m^3.

Work elements in forwarding are shown in Figure 3. The forwarding time during trials was considerably increased by snow-fall that took place some days after harvesting. Most of productive time was spent to find assortments below snow and to identify different categories of assortments; therefore, the most time consuming work element in these forwarding studies was unpredicted operations. Considering that such a situation might take place in reality, especially in winter this work element was not excluded from productive work time.

Structure of forwarding work elements depending on work method is shown in Figure 4. The highest productivity figures are characteristic to work methods with a larger share of biofuel. Less productive is work method 1, because of smaller concentration of assortments (more driving from pile to pile).

Productive forwarding time (min. per load) for different work methods is:

1. work method – loading 36 min., unloading 4 min., average load 6.6 m^3,
2. work method – loading 38 min., unloading 4 min., average load 7.3 m^3,
3. work method – loading 19 min., unloading 3.4 min., average load 5.6 m^3,
4. work method – loading 16 min., unloading 2.9 min., average load 5.0 m^3,
5. work method – loading 23 min., unloading 3.5 min., average load 6.0 m^3.

Average loading time 26 min, unloading 3.6 min, average load 6.0 m^3. Average driving speed 68 m min^{-1}.

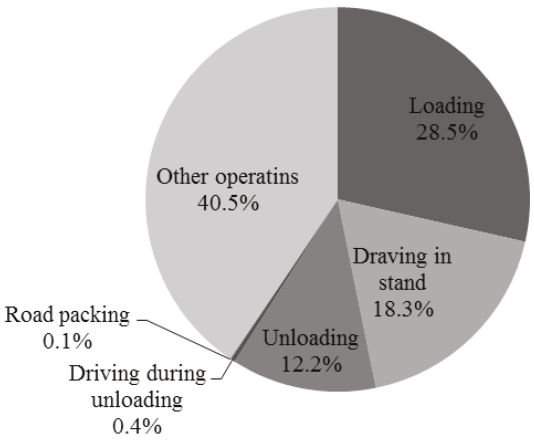

Figure 3. Average distribution of work elements in forwarding.

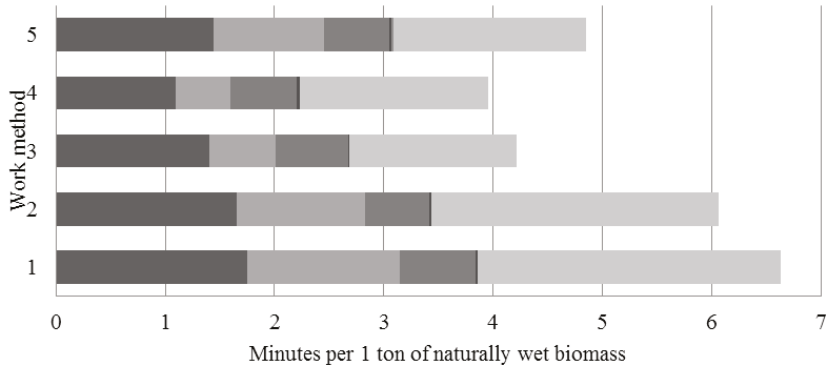

Figure 4. Structure of forwardig work elemets depending from work method.

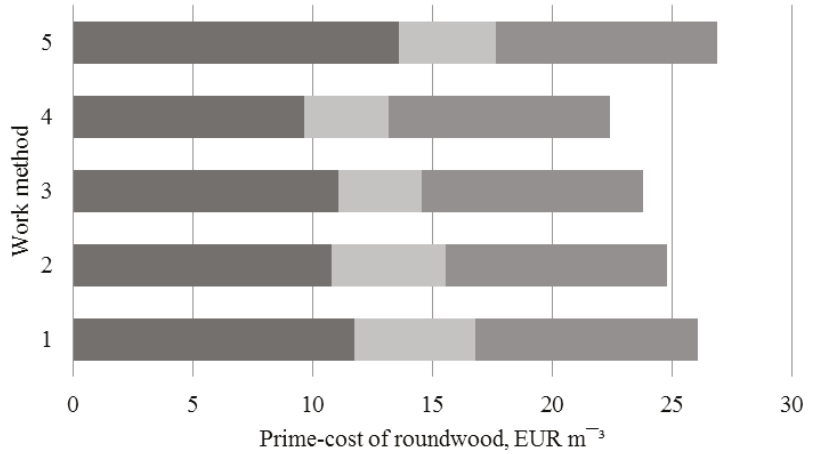

Figure 5. Structure of prime-cost of production and delivery of round-wood matherial.

The structure of prime-costs of production and delivery of round-wood material depending on work method is shown in Figure 5. If work method 5 is not considered (because of smaller dimensions of extracted trees and, respectively, higher production cost), the most efficient is the 4th method. Although the cost of production and delivery of round-wood materials depending on work method ranges from 22 (work method No.1) to 27 (work method No. 2) EUR m^{-3} and differences from the economical point of view are considerable, differences between work methods are not statistically significant ($p<0.05$).

Prime-cost of round-wood considerably drops if a part of cost equal to standard motor-manual thinning is excluded (Figure 6). In spite of that, the production cost is still too high to produce only biofuel assortment in pre-commercial thinning. Market price of firewood utilized in pellet production (respectively, accounted under bark) is 23 EUR m^{-3} on average; therefore, the risk of failure (economic losses) is very high for all methods. There are no statistically significant differences ($p<0.05$) between work methods.

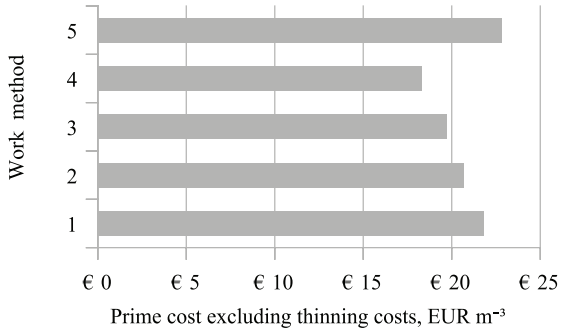

Figure 6. Prime-cost of round-wood excluding thinning cost.

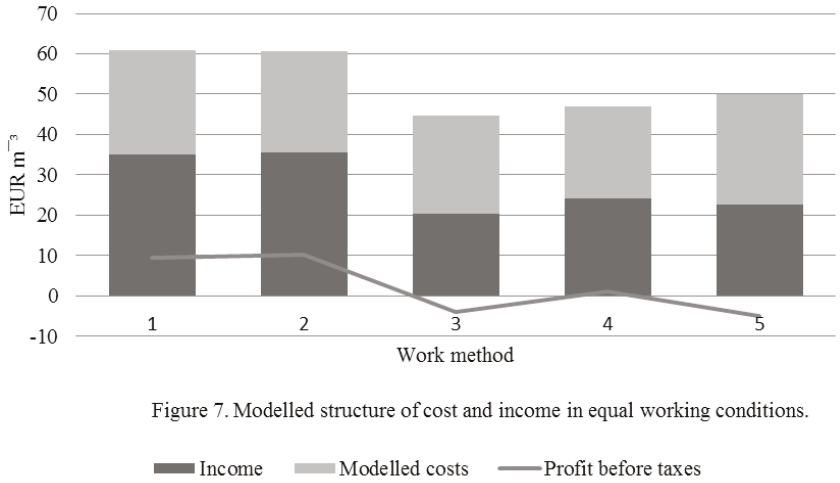

Figure 7. Modelled structure of cost and income in equal working conditions.

Potential income from selling round-wood is considered in a separate calculation of modelled structure of cost and income in equal working conditions. According to Figure 7, working methods 3 … 5 are related to high risk of negative net income; but the most profitable method is No 2 – production of standard assortments and biofuel from undergrowth trees considering reduced min. top diameter of biofuel logs (30 mm).

There are no statistically significant differences ($p<0.05$) between work methods.

Conclusions

1. Average amount of round-wood (under bark) produced in thinning is 28 m^3 ha^{-1}. Share of firewood is 20 – 100%.
2. The average productivity in different stands is statistically different. In stands where only biofuel is prepared, the average productivity was 155 trees per productive hour, but in stands where also other assortments are prepared, the average productivity was 135 trees per productive hour.
3. Comparison of work methods demonstrates an increase in productivity of harvesting with reduction of the number of assortments, except work method 5, where the average diameter of trees was considerably smaller than in other stands. Productivity of harvesting is 3.7 … 5.1 m^3 h^{-1}. Productivity can be increased by more intensive use of accumulation (only 20% working cycles in the study contained more than 1 tree).
4. No difference was found between work methods in forwarding trials, but productivity grows with increase of share of firewood. An average loading time is 26 min, unloading is 3.6 min., but an average load - 6.0 m^3. An average driving speed is 68 m min^{-1}.

References

1. Kalēja S., Brencis M., Lazdiņš A. (2014) *Apaļo kokmateriālu un šķeldu piegādes ražīguma salīdzinājums jaunaudžu kopšanā* (Comparison of delivery productivity of roundwood and woodchip in young stand tending). Latvijas Valsts mežzinātnes institūts 'Silava', Salaspils, 38 lpp. (in Latvian).
2. Laina R., Tolosana E., Ambrosio Y. (2013) Productivity and cost of biomass harvesting for energy production in coppice natural stands of *Quercus pyrenaica* Willd. in central Spain. *Biomass and Bioenergy.* 8, pp. 221 – 229.
3. Lazdāns V. (2006) *Enerģētiskās koksnes resursu vērtējums, to sagatavošanas tehnoloģijas un izmaksas, veicot kopšanas cirtes 20 - 40 gadus vecās mežaudzēs* (Energy wood resource assessment, preparation technology and the costs of the thinning 20 - 40 year-old stands). Latvijas Valsts mežzinātnes institūts 'Silava', Salaspils, 70 lpp. (in Latvian).
4. Lazdāns V., Lazdiņš A., Zimelis A., Nordén B., Iwarsson – Wide M. (2008) *Forest energy from small-dimension stands, 'infra-structure objects' and stumps*, The Forestry research Institute of Sweden 'Skogforsk', Latvijas Valsts Mežzinātnes Institūts 'Silava', Uppsala, 44.p.
5. Lazdiņš A. (2013a) *Darba metodes ietekme uz griezējgalvas Bracke C 16.b ražīgumu jaunaudžu kopšanā* (Impact of work methods on productivity of young stand tending with cutting head Bracke C16b). Latvijas Valsts mežzinātnes institūts 'Silava', Salaspils, 60 lpp. (in Latvian).
6. Lazdiņš A. (2011d) Preconditions for efficient management of naturally afforested farmlands. Summary of the Doctoral thesis for the scientific degree Dr.in Forest Ecology and Silviculture. Available at: http://llufb.

llu.lv/dissertation-summary/forestry/Andis_Lazdins_prom_darba_kopsavilkums_2011_LLU_MF.pdf, 2 February 2014.

7. Lazdiņš A. (2013c) *Sortimentu struktūras ietekme uz kopšanas un pievešanas ražīgumu lapkoku audzēs* (Impact of assortiment structure on productivity of harvesting and forwarding in deciduous stands). Latvijas Valsts mežzinātnes institūts 'Silava', Salaspils, 60 lpp. (in Latvian).
8. Lazdiņš A., Zimelis A., Lazdāns V. (2012) *Enerģētiskās koksnes sagatavošanas tehnoloģijas kopšanas cirtēs, galvenās izmantošanas cirtēs un mežu infrastruktūras objektos* (Technologies of energy wood preparation in young stand tending, in main cutting and in forest infrastructure). Latvijas Valsts mežzinātnes institūts 'Silava', Salaspils, 143 lpp. (in Latvian).
9. Lazdiņš A. (2013b) *Roku darba ražīguma un biokurināmā izmaksu novērtējums jaunaudzēs* (Estimation of productivity of hand-work and costs of biofuel in young stands). Latvijas Valsts mežzinātnes institūts 'Silava', Salaspils, 5 lpp. (in Latvian).
10. *Meža enciklopēdija* (Encyclopedia of Forest) (2003) Zelta grauds, Rīga, 281 lpp. (in Latvian).
11. Sirén M., Aaltio H. (2003) Productivity and Costs of Thinning Harvesters and Harvester-Forwarders. *Journal of Forest Enginnering.* 14, pp. 39 – 48.
12. Walsh D., Strandgard M. (2014) Productivity and cost of harvesting a stemwood biomass product from integrated cut-to-length harvest operations in Australian *Pinus radiate* plantations. *Biomass and Bioenergy.* 66, pp. 93 – 102.

FACTORS AFFECTING PRODUCTIVITY AND COST OF SOLID BIOFUEL IN MECHANIZED FOREST DITCH CLEANING

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Abstract
The study represents results of productivity studies of mechanized ditch cleaning using Ponsse Fox harvester adapted to multi-tree handling H6 head in forest drainage systems managed by Joint stock company "Latvia state forests". The aim of the study is to evaluate productivity of extraction of biomass from ditches depending on working method and to estimate factors affecting prime-cost of biofuel in mechanized harvesting. The study results demonstrate that the 2nd method (mechanized extraction of roundwood and following motor-manual cleaning of remaining vegetation) is the most efficient solution for mechanized cleaning of ditches. Benefits of the 2nd method are smaller costs of undergrowth removal and bigger output of solid biofuel. Ponsse Fox harvester demonstrated sufficient work quality and productivity in the trials; however, it would be wise to use heavier harvesters or caterpillar excavator based harvesters in ditch cleaning. Using the 2nd method, a harvester can extract about 227 ha of ditches (23,000 m^3) annually.
Key words: ditch cleaning, solid biofuel, mechanized harvesting.

Introduction

Biomass in roadside and ditch cleaning operations is an undervalued resource of solid biofuel in Latvia having considerable potential to grow. Considering fragmented land use and ownership structure, the amount of biomass growing in the forest infrastructure differs from case to case – it could be from some trees to several tens of thousands of trees per ha, resulting in complicated to estimate and to harvest type of biofuel. In most cases work with roadside and ditch cleaning means small dimensions of trees, where the height of average tree only sometimes exceeds 12 m (Skogforsk, 2011; Thor et al., 2008).

The latest studies on mechanized extraction of small size trees for solid biofuel production in ditch cleaning in cooperation among the Joint stock company "Latvia state forests", Latvia State forest research institute 'Silava' and Swedish forest institute Skogforsk were implemented in 2007...2008. The study approved that the average drainage ditch covered by woody vegetation can deliver about 100 LV m^3 ha^{-1} (LV – loose volume) of high quality solid biofuel applicable in pellet production as well as for plate wood production. The average age of trees in these ditches is 15...20 years (Thor et al., 2008).

According to results of the earlier studies woody vegetation on drainage ditches should be harvested once per 15...20 years, in conjunction with thinning or felling of neighbouring stands and reconstruction of drainage system if necessary. In state forests, every year 2,000...3,000 ha of drainage ditches should be harvested producing 0.2...0.3 mill. LV m^3 of solid biofuel annually (Thor et al., 2008; Lazdiņš and Thor, 2009). Resources of solid biofuel in drainage systems of private forests have not been evaluated yet.

The studies in 2007...2008 demonstrated the average extraction productivity of 8.2 LV m^3 per productive hour. This is a relatively low value if compared with productivity in Sweden and prerequisites for feasible logging at roadsides. The Bracke C16.a harvester head secured 25% higher productivity, including forwarding of small trees in comparison to Ponsse guillotine type EH25 felling head. Both devices produced full tree assortment. The price of mechanized extraction and delivery of chipped solid biofuel in 2008 for EH25 installed on Ponsse Gazelle forwarder was 7.70 Ls LV m^{-3} and for Bracke C16.a installed on John Deere 970 harvester was 6.37 Ls LV m^{-3}; respectively, 11 and 9.1 EUR LV m^{-3}. At that time the market threshold for wood chips was about 8.5 EUR LV m^{-3}. Thus, it was decided that it was too early to implement mechanized ditch cleaning due to low profitability. The study also demonstrated problems in skill of operators and maintenance of machinery (Lazdiņš and Thor, 2009; Thor et al., 2008). Studies on mechanized ditch cleaning were done in Sweden in 2009...2010 selecting objects, where the number of growing trees was 4,000...20,000 per ha with total growing stock of 40...110 tons ha^{-1}. The average productivity in the studies was 2.6...3.7 tons per hour using accumulating felling head (Skogforsk, 2011); it means twice higher than in earlier studies in Latvia. The profit before taxes was 1000 EUR ha^{-1}. However, the tested method can be applied only to 5% of roadsides in Sweden (10,000 ha), corresponding to 2 TWh of primary energy (Skogforsk, 2011).

Studies in Latvia and Sweden demonstrated that it is important to extract only the biggest trees, leaving small ones ($D_{1.3}$ < 4 cm) on the ground or untouched. The extractable growing stock should be at least 40 tons ha^{-1} (200 LV m^3) to secure positive cash flow. If there are lots of trees with $D_{1.3}$ < 3 cm, it is recommended to combine the harvester with

accumulating felling head and biomass mulcher to clean the roadside completely. The normal procedure would be to take larger trees with a harvester and then cut and crush remaining vegetation (Skogforsk, 2011).

In Latvian state forests valuable woody vegetation covers 10.8% of ditches and mixture of trees and bushes 43% of ditches with total biofuel production potential of 0.4...0.5 mill. LV m^3 annually. The average growing stock ranges from 20 to 250 LV m^3 ha^{-1} (Lazdāns et al., 2008).

The aim of the study was to evaluate productivity of extraction of biomass from ditches depending from working method and to estimate factors affecting prime-cost of biofuel in mechanized harvesting.

Materials and Methods

The experiment was implemented in January – February, 2013. The studied working methods are:

- a harvester cuts all trees higher than 2 m, no manual operations necessary (method 1);
- a harvester cuts all trees and bushes thicker than 4 cm, then remaining bushes are removed manually (method 2);
- manual cut of deciduous having diameter ($D_{1.3}$) at 1.3 m height more than 10 cm and coniferous having $D_{1.3}$ more than 8 cm with mechanized removal of remaining trees (method 3, standard).

Accumulating function was used in the 1st and 2nd method, because of quality requirements of pulpwood, which prohibits application of multi-tree handling in production of standard roundwood.

The harvester Ponsse Fox with H6 head equipped to be able to process simultaneously several trees was used in the study. Feed rolls were used for accumulation of trees; a harvester program was able to manage multi-tree processing. A logset 4F forwarder was used in forwarding of roundwood. Load capacity of the machine is 10 tons, weigh of fully loaded machine is 23.5 tons. Crane length is 7.2 m. Mostly mixed loads were transported to roadside storage (up to 4 assortments per load). Every forwarder load was weighed with CAS RW-15P scales consisting of 2 platforms installed on separate steal or wooden base. Maximum weight that can be measured by each platform is 15,000 kg, uncertainty – 10 kg.

In total 32 ditches with the area of 16.4 ha and total length of 14.6 km were selected for the studies; harvesting trials were done in 16 ditches, a provider of harvesting and forwarding service was SIA "Betta serviss" company. Operators had previous experience with this type of operations.

The average diameter of trees higher than 2 m in all ditches was 9 cm, height 8 m, basal area – 15 m^2 ha^{-1}, number of trees – 1,761 per ha^{-1}, growing stock – 106 m^3 ha^{-1}, above-ground biomass – 52 tons ha^{-1}. Additionally, 312 trees and bushes per ha^{-1} being shorter than 2 m had to be cut down in all ditches (in case of mechanized extraction, 18% of all extractable trees would be 2 m high or shorter). The structure of vegetation differed between ditches and within a single ditch. Total growing stock in all measured ditches was 1,759 m^3, above-ground biomass – 843 tons. Diameter distribution (Figure 1) shows that most of the trees on ditches have 3-5 cm diameter, but the growing stock is equally distributed in 10 – 30 cm diameter range; therefore, in case of mechanized extraction most of time would be spent on cutting trees that have a very small volume, and it is important to use accumulating function as much as possible with small size trees to increase volume of wood processed per crane cycle.

Wood samples were collected from each storage site right after forwarding by selection 10 logs of up to 4 of the most common species in the storage representing the smallest, the largest and moderate bottom diameter of logs. Wood chips samples were collected 17 days after forwarding during chipping of the material. Samples of wood chips were collected from every load, when it was full or after switching

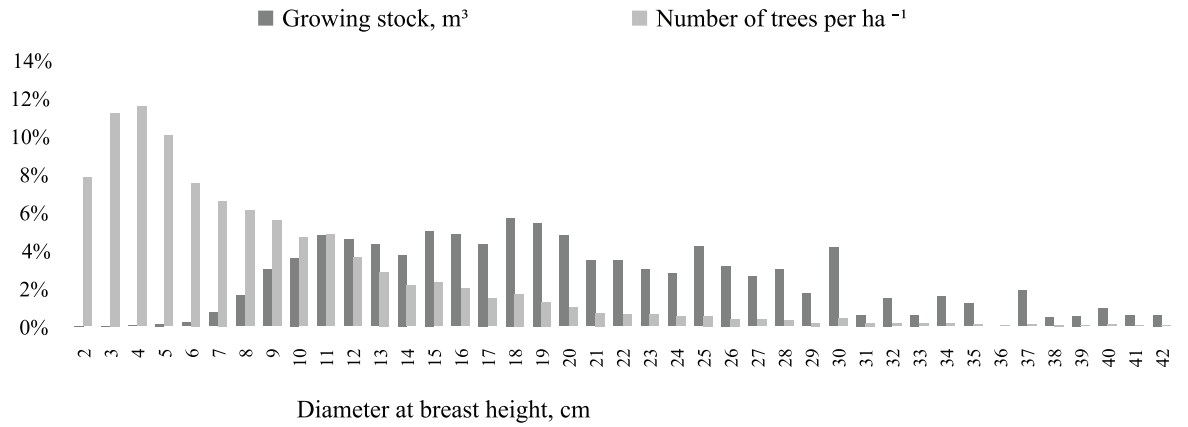

Figure 1. Diameter distribution of number and stock of trees on ditches.

to another storage yard. Biomass in all storage yards was chipped with EUROPE Chippers 1060 on an emergency truck base.

Standard analytical methods were used to determine particle size distribution in chips, moisture content in chips and logs, ash content in chips and logs, bulk density of chips as well as for sampling of chips during chipping operation (CEN, 2005; Swedish Standards Institute, 2005a; b, 2006a; b).

The outdoor temperature in February, 2013 (between forwarding and chipping) was by 3 °C higher than the average temperature of the last decade in this month. The amount of precipitation in the period between forwarding and chipping was 36 mm, no significant difference from previous decade was found.

Time studies were done for extraction, forwarding, manual cleaning of remaining vegetation and chipping of material. Productivity figures for roundwood and chip transport were taken from earlier studies (Thor et al., 2006; Thor et al., 2008; Lazdiņš and Thor, 2009; Kalēja et al., 2013). FLISS derived costing model was used in calculation of cost of biofuel and roundwood production and deliveries assuming that biofuel is delivered to a customer as chips (Thor et al., 2006; Skogforsk, 2009).

Results and Discussion

Direct productive time (time without driving into and out of the stand) for extraction of one tree in all methods on average is 44 sec., per 1 ha – 663 min. (11 hours), for 100 m of ditch – 75 min., for production of 1 m^3 of logs – 9 min. (6.7 m^3 per hour). The longest time per tree and per 100 m of ditches is characteristic for the method No. 3 (a harvester cuts trees after manual cleaning of undergrowth). The most efficient is the method No. 2. Smaller productivity in the 3rd method is the result of an increase of average diameter of mechanically extractable trees after removal of undergrowth; respectively, an accumulating function can be applied to limited number of trees, thus significantly reducing productivity. Reduction of productivity in the 1st method is the result of more complicated quality requirements – the harvester had to manage very small stems spending time for removal of remaining undergrowth trees and bushes. Direct productive time is 82% of scheduled work time and 91% of total productive time, including driving into and out of the stand.

The greatest difference between working methods at harvesting stage derives from bucking operation, which is much more time consuming in the 3rd method (Figure 1). The 1st method requires considerably longer time for other operations (undergrowth removal). The longest tree processing time in the 3rd method can be explained by considerably larger dimensions of trees so that nearly all trees have to be processed using a single tree method to produce traditional assortments.

The exponential equations demonstrating impact of diameter of trees on productivity of harvesting are shown in Figure 2. The use of the 1st method is beneficial if a diameter of trees reaches standard conditions in the final felling, the 2nd method is more beneficial than the 1st in case of small size trees and more beneficial than 3rd method in all diameter classes.

The linear regression (Figure 3) characterizing this correlation can be used in practise to determine growing stock on ditches.

In total, 845 tons of material are forwarded (116 loads), average load – 7.3 tons. The biggest load – 13.2 tons (27 tons with a tractor). Biofuel (partially delimbed logs) loads were comparably smaller than other loads. The average load of biofuel 5.7 tons (2.6 tons of dry mass or 13 MWh). The average load is 3.3 tons of dry mass. On average, loading and unloading of 1 ton of naturally wet material took 7.2 minutes, but loading and unloading of 1 m^3 – 1.6 minutes.

Considerably higher productivity figures were found in the 2nd method (Figure 4), because assortments are located more concentrated and extracted stock is larger, so driving and other operations takes less

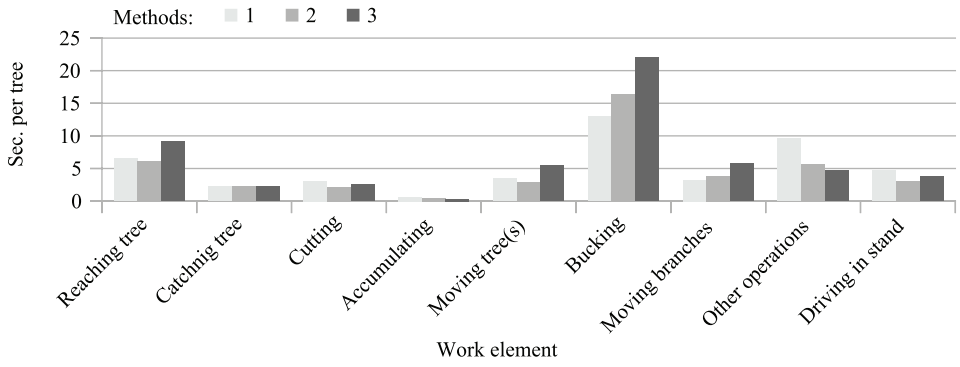

Figure 2. Duration of operations depending from work method.

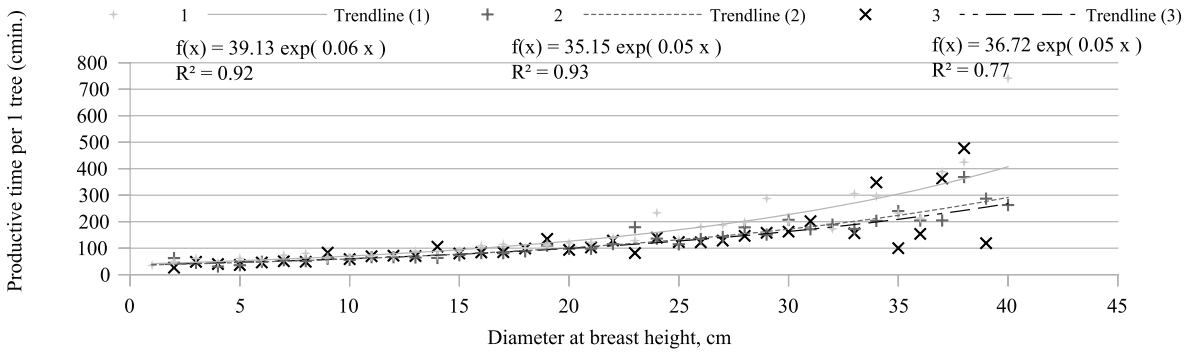

Figure 3. Equations to characterize harvesting productivity depending on work method.

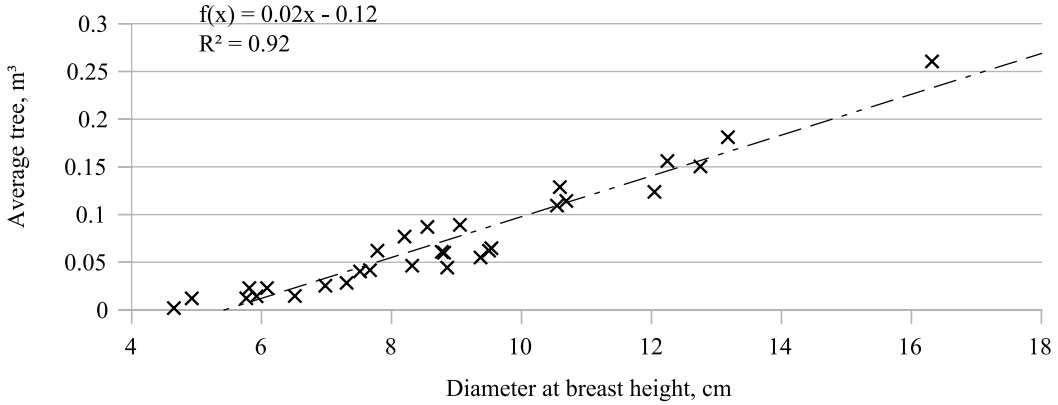

Figure 4. Equation to characterize diameter of average tree and stem volume.

time than for the 3rd method. Productivity goes down in the 1st method because of smaller dimensions of stems. However, no statistically significant difference was found in total forwarding time depending on the harvesting method; therefore, average figures were used in prime cost calculation.

Most time consuming operation was loading, followed by the other (including finding and separation of different assortments), driving in stand and unloading.

In total, 510 LV m³ of chips were produced and 7 loads delivered to a customer. The average load was 73 LV m³. Consumption of productive time for chipping was 37 sec. LV. m³, share of productive time 67% of scheduled work time. On average, the production of 1 ton of dry matter of solid biofuel requires 178 sec. of productive time. Productivity of chipping can be considerably increased by the reduction of delays and by the use of chipper with better carriage design (logs should not be pushed down to keep on carriage). On average, this operation took 28% of productive work time.

Besides solid biofuel 981 m³ (under bark) of roundwood assortments were produced in the trials (2,363 MWh of primary energy). The output of solid biofuel equals to 555 MWh (23% of the amount of round-wood assortments). Every 100 m³ of roundwood assortments equal to 52 LV m³ of chips, corresponding to 57 MWh of primary energy.

The prime-cost of round-wood logs and wood chips with 5% profit margin depending on the selected working method, including delivery to 50 km distance, is:

- the 1st method – 1 m³ of saw-logs cost 26.0 EUR, but prime cost of 1 LV m³ wood chips – 14.3 EUR;
- the 2nd method – 1 m³ of saw-logs cost 19.3 EUR, but 1 LV m³ wood chips – 11.1 EUR;
- the 3rd method – 1 m³ of saw-logs cost 17.4 EUR, but 1 LV m³ wood chips – 10.1 EUR.

Manual operations – removal of undergrowth (3rd method) and cleaning of remaining woody vegetation (2nd method) is considered in calculation according to study data.

Volume of average tree is the main factor affecting prime cost – in the 1st and 2nd work method it is considerably smaller than in the 3rd work method; therefore, the average productivity in the 3rd method

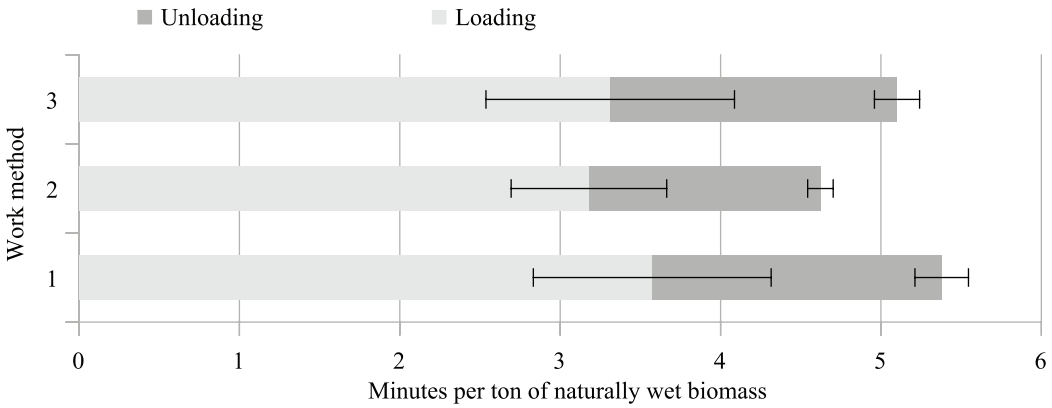

Figure 5. Productivity of loading and unloading.

is the highest in the experimental sites. Application of the 2nd method significantly reduces time consumption and cost for undergrowth removal after mechanized extraction.

The smallest cost using the 3rd method is determined by a larger volume of trees (after removal of undergrowth average diameter of extractable trees theoretically increased by 55%, but the number of extractable trees decreased by 58%). At the same time the undergrowth removal reduced extractable biomass only by 5%.

If compared, in equal conditions, the 1st method is more beneficial in case of small diameter of average tree (Figure 5). Productivity of the 2nd method can be raised by an increase of lower limit of extractable tree from 4 to 6 or 8 cm, so that smaller trees are extracted only in case if they can be cut and processed simultaneously with larger trees.

The best balance between income and expenses can be reached using the 2nd work method (Figure 6); however, it is determined largely by dimensions of trees and assortments' structure (ditches in the 2nd work method were characterized by large proportion of coniferous trees).

In practical work the 2nd method can be improved by increase threshold diameter value for extractable trees and by more intelligent selection of work method depending on the structure of woody vegetation in a particular object. It is also important that the 2nd method provides an opportunity to increase considerably the output of biomass from ditch cleaning in comparison to the 3rd method. The 1st method cannot be widely applied in practice using a standard harvester head, because it is not possible to meet internal quality requirements of the Joint stock company 'Latvia state forests', using this type of felling heads.

The average relative moisture of biomass directly after forwarding is 55%; the highest level of moisture is found in spruce wood (60%), then grey alder and black alder followed with, 57 and 56%, respectively. The driest is birch wood. The largest bulk density is found in birch logs (0.49 kg L^{-1}), the smallest – in spruce logs (0.38 kg L^{-1}). The average bulk density in all samples is 0.43 kg L^{-1}. The primary energy content of wood is 2.6...2.0 MWh m^{-3}. Moderate correlation between bottom diameter and relative moisture found only for black alder (r=-0.59), but correlation between bottom diameter and bulk density – for birch (r=0.41).

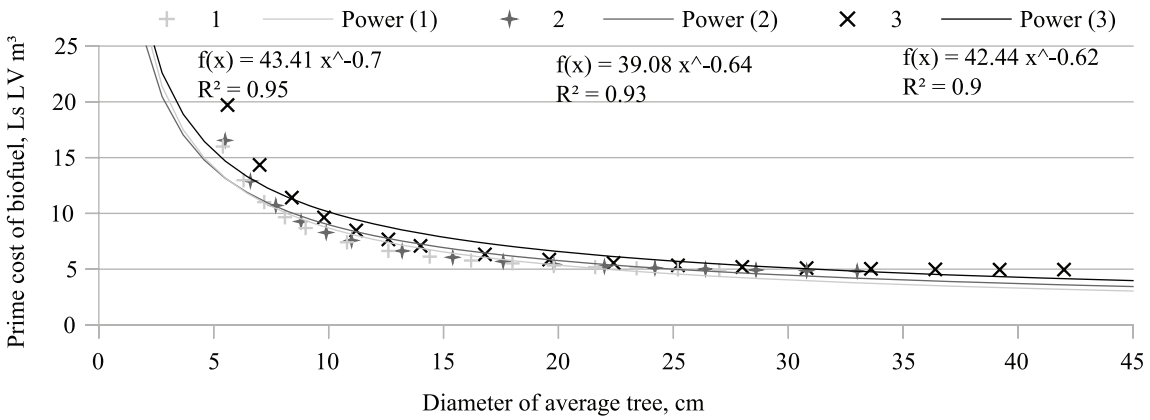

Figure 6. Comparison of different methods in equal conditions (the same $D_{1.3}$).

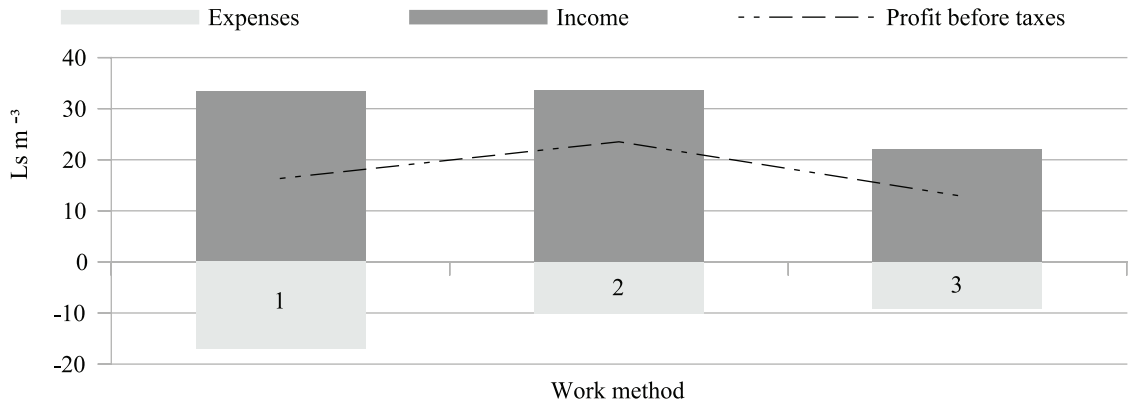

Figure 7. Comparison of income and expenses in different methods.

If compared to different storage yards, the driest wood is found in storages with the highest proportion of birch. No such correlation was found for bulk density. Different density of wood requires special attention to forwarder loads to avoid overloading, when birch dominant loads are transported.

Relative moisture of chips was 47%, it means that it is considerably smaller than during forwarding (from 55% or on average by 0.5% per day). Bulk density of naturally wet chips was 0.40 kg L^{-1}, but of absolutely dry wood – 0.21 kg L^{-1} (weight of full load of chips in 90 m^3 truck is about 36 tons). Primary energy content of chips is 1 MWh LV m^{-3}. Largest fractions of chips are 45-16 mm and 16-3.15 mm (89% by mass), a small fraction below 3.15 mm is 8% by mass. Content of ash in produced chips is 0.68%. These chips can be used both, for industrial and premium class pellets; however, for production of premium class pellets the customer has to receive logs and not chips to debark them before crushing. Debarking most probably would decrease the amount of ash in raw material for pellet production; however, delivery of roundwood would considerably increase prime-cost of solid biofuel.

Conclusions

1. The 1st method cannot secure the implementation of quality requirements set by JSC "Latvia state forests". The method can be utilized, if the number of undergrowth trees and bushes is insignificant, specifically as a part of the 2nd method in suitable areas.
2. The 2nd method is the most efficient solution for mechanized cleaning of ditches, because it provides the best combination of assortments structure resulting in higher income and good productivity figures, both in harvesting and forwarding. Another benefit of the 2nd method is smaller cost of undergrowth removal. However, it would be wise to increase minimal diameter of mechanically extractable tree to 6...8 cm.
3. Working with the 2nd method, a harvester can extract about 227 ha of ditches (23,000 m^3) annually. This means that 3 harvesters can be utilized to full extent in ditch cleaning in state forests.
4. Productivity of forwarder in ditch cleaning operations is considerably larger than average in commercial thinning and final felling. When using small forwarders in birch or black alder dominant vegetation, the loads should be considerably smaller than in coniferous stands to avoid overloading of the machine.

Acknowledgements

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References

1. Kalēja S., Grīnfelds A., Lazdiņš A. (2013) Economic value of wood chips prepared from young stand tending. In *Annual 19th International Scientific Conference Proceedings*, Vol. 2 of 2, Jelgava, Latvia University of Agriculture, pp. 66 – 73.
2. Lazdāns V., Lazdiņš A., Zimelis A. (2008) *Meža infrastruktūras objektu kopšanā iegūstamo enerģētiskās koksnes resursu aprēķinu metodikas izstrāde*. Pārskats par Meža attīstības fonda pasūtītā pētījuma izpildi (Elaboration of methodology for calculation of wood resources accessible in forest infrastructure cleaning operations. Forest development fund project report). 75 lpp. (in Latvian).

3. Lazdiņš A., Thor M. (2009) Bioenergy from pre-commercial thinning, forest infrastructure and undergrowth – resources, productivity and costs. In *Annual 15th International Scientific Conference Proceedings*, Jelgava: Latvia University of Agriculture, pp. 147 – 154.
4. Skogforsk (2011) *Efficient forest fuel supply systems Composite report from a four year R&D programme 2007-2010*. Uppsala Science Park, S-751 83 Uppsala, 116 p.
5. Skogforsk (2009) FLISavFLIS. Available at: https://www.skogforsk.se/sv/butiken/Program/FLISavFLI/, 14 March 2014. (in Swedish).
6. Thor M., Iwarsson-Wide M., Von Hofsten H., Nordén B., Lazdiņš A., Zimelis A., Lazdāns V. (2008) *Forest energy from small-dimension stands, infra-structure objects and stumps (research report),* Uppsala Science Park, S-751 83 Uppsala, 75 p.
7. Thor M., Von Hofsten H., Lundström H., Lazdāns V., Lazdiņš A. (2006) *Extraction of logging residues at LVM (research report)*. Uppsala, 36 p.
8. CEN (2005) *FINAL DRAFT prCEN/TS 15149-1 Solid biofuels - Methods for the determination of particle size distribution - Part 1: Oscillating screen method using sieve apertures of 3,15 mm and above*. EUROPEAN COMMITTEE FOR STANDARDIZATION.
9. Swedish Standards Institute (2005a) *SIS-CEN/TS 14774-2:2004 Solid biofuels – Methods for the determination of moisture content – Oven dry method – Part 2: Total moisture – Simplified method*. Swedish Standards Institute.
10. Swedish Standards Institute (2005b) *SIS-CEN/TS 14775:2004 Solid biofuels – Method for the determination of ash content. Swedish Standards Institute*.
11. Swedish Standards Institute (2006a) *SIS-CEN/TS 14778-1:2006 Solid biofuels – Sampling – Part 1: Methods for sampling*. Swedish Standards Institute.
12. Swedish Standards Institute (2006b) *SIS-CEN/TS 15103:2006 Solid biofuels – Methods for the determination of bulk density.* Swedish Standards Institute.

TESTING THE 'ROTSTOP' BIOLOGICAL PREPARATION FOR CONTROLLING *HETEROBASIDION* ROOT ROT IN LATVIA

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Abstract
In Latvia, *Picea abies* and *Pinus sylvestris* as the commercially most valuable species make more than half of all woodlands. It has been found that about 23% of spruce stands are infected by root rot, caused predominantly by fungal pathogen *Heterobasidion annosum* s.l. To restrict the spread of root rot in coniferous forests of Latvia, the Joint Stock Company 'Latvijas valsts meži' collaborated with Latvian State Forest Research Institute 'Silava' in 2006 and launched a project for testing the Rotstop biological preparation, containing a suspension of *Phlebiopsis gigantea* spores. This project had a general task to accomplish Rotstop using technology approbation in Latvia and develop control system. Starting with the year 2008, preparation was used for stump treatment during thinning operations. When analysing the field data, a conclusion made in other studies was confirmed - *P. gigantea* colonizes pinewood more intensively even in case of improper stump treatment. It implies that the quality of stump treatment is decisive when using Rotstop for rot control in spruce stands.
Key words: *Phlebiopsis gigantea*, *Heterobasidion annosum*, thinning, quality control, Rotstop.

Introduction

With forests covering 50.9% of the country's territory and the conifers accounting for 54% of the total woodland area (2014 State Forest Service data) about 23% of spruce *P. sylvestris* stands are infected by root rot, caused predominantly by such fungal pathogen as *Heterobasidion annosum* s.l. (Arhipova et al., 2010). *H. annosum* spreads by fungal mycelium when infected tree roots come into contact with the roots of adjacent healthy trees, and by basidiospores, which infect tree stumps right after felling (Hodges, 1969). In standing trees the *H. annosum* infection causes white rot of tree roots and stem, which may spread as high as 12 m (Stenlid and Wästerlund, 1986). In the EU, the annual losses to forestry caused by this pathogen are estimated at EUR 790 million (Woodward et al., 1998). As a result, the timber quality is lower and the forests become more susceptible to different biotic and abiotic damages. The spread of *H. annosum* is closely related to the existing management practices. Mechanized timber harvesting favours the infection of tree stumps and damages stems and roots by fungal spores both in the remaining stands and restocked cutovers.

It is possible to control the spread of *H. annosum* at any stage of its life cycle (Asiegbu et al., 2005). Silvicultural methods of control include restocking the respective site by the tree species other than the infected one, for instance, by pine *P. sylvetris* or broadleaves instead of spruce *P. abies* (Piri, 1996; Piri and Korhonen, 2001). There is a possibility also to establish mixed stands which are less susceptible to *H. annosum* (Arhipova et al., 2010), or reduce the number of young trees per unit area, thus reducing the need for thinning out the dominant species (Epstein, 1978), or carry out thinning operations in winter (Rönnberg, 2000). One of the methods that could be used is no thinning in heavily infected sites, thus reducing the rotation cycle of infection-sensitive stand (Bendz-Hellgren et al., 1999). Stubbing of infected stumps appears to be one of the most efficient methods for mitigating the risk of *H. annosum* infection (Rishbeth, 1951; Hodges, 1969; Vasaitis et al., 2008; Cleary et al., 2013), including removal of all infected wood from the forest site (Schütt and Schuck, 1979; Müller et al., 2007; Stivriņa et al., 2010). The other method that could be used is the treatment during logging operations of fresh stump surfaces by borate and carbamide solvents, or using preparations which contain a suspension of *Phlebiopsis gigantea* spores (Woodward et al., 1998).

In forestry, thinning, carried out properly and in due time, is one of the major preconditions for achieving a tree stand of high productivity in the future. Still, in thinning operations we leave a lot of stumps behind, which is one of the risk factors that the future crop trees might be rot-infected. Unlike the Scandinavian countries, known as an avanguard of modern forestry, in Latvia the stump treatment in thinnings by *H. annosum* controlling biological preparations was not practiced. In 2006, the Joint Stock Company 'Latvijas valsts meži' (LVM), after studying the experience of Finland and Sweden in this respect, decided to test the above mentioned method and implement it in practical forestry. The LVM, involving the leading research scientists, Finnish experts, and local service providers in forest management, launched a project for field-testing the above mentioned method, including personnel training. The method of applying the Rotstop preparation in fungal pathogen

control, the related regulatory documentation and the quality control system are among the outputs of this project. In the meantime, the efficacy of the Rotstop preparation was tested so as to achieve its official registration in Latvia. Starting with 2008, in order to reduce the risk of root rot infection, the LVM has been using the biological fungicide Rotstop for treating the stumps in thinning conifer stands. To evaluate the efficiency of this method, starting with 2008 samples of stumpwood for laboratory analyses are annually collected in randomly chosen twenty recently cut stands. The objective of this study was to evaluate the quality of Rotstop treatment and the presence of Rotstop and natural *P. gigantea* strains in treated conifer stumps. Project experts regularly take LVM personal trainings to improve knowledge about root rot and Rotstop using.

Materials and Methods

This Rotstop approbation experiment was organised in Zemgale and Ziemeļkurzeme LVM regional branches in the year 2006 in thinning (stamps treated to harvest 5448 m^3 conifer wood) and finally cuttings (stamps treated to harvest 7200 m^3 conifer wood).

Potential for restricting root rot

Field-tests in thinning of the preparations for controlling the *Heterobasidion* root rot suggest that for the conditions of Latvia those containing the spore suspension of *P. gigantea* appear to be the most efficient ones. Among the known preparations of this kind the Polish preparation PG-IBL, in which *P. gigantea* spores are in a mix with conifer sawdust, the British PG Suspension, and the Rotstop of similar composition developed in Finland, which was the most efficient one for Latvia also with regard to the manufacturing methods and supplies are worth mentioning. The latter has been used for controlling *H. annosum* since 1993 in Scandinavian countries.

Preparing the Rotstop spray solution and the method of its application

The preparation should be kept in a refrigerator or cold storage. To keep the *P. gigantea* spores alive, in preparing the spray solution its temperature should not exceed 40 °C.

The Rotstop spray solution is prepared as provided by the manufacturer's instructions (www.verdera.fi), dissolving the preparation in water at a ratio one gram per one litre of water. The final solution looks somewhat muddy. One or two tablets of the Turf Mark dye, depending on the operator's experience, should be added to the solution to control the quality of stump treatment. The spray solution should be used up within 24 hours. Taking into account the ecological and economic aspects of pathogen control, in the process of thinning, it is recommended to treat the stumps by this preparation in tree stands on mineral soils, where the proportion of conifers exceeds 50% and the area of the respective site is not less than one hectare.

Methods of Rotstop application

The Rotstop solution may be applied to stumps simultaneously with the harvester's felling head severing the tree stem from the stump or by a manual sprayer after specified intervals. The former method is the most efficient one, as the spray solution is pressure-applied through holes in the guide bar of the cutter at the moment the tree stem is cut down. This method ensures a high quality of stem treatment, which is essential for efficient Rotstop application. The use of manual sprayer is recommended in case of motor-manual felling. The treatment ought to be carried out within an hour after felling, i. e. after each successive instance of refilling the fuel tank; the average time span between refillings is about 45 minutes (2014 Verdera).

Quality control of stump treatment

The quality control of stump treatment by rot-suppressing agents is necessary because for the forest manager this operation is normally an outsourced service. For this purpose a special method of quality control has been worked out, which envisages three levels of control. In the first level of control the harvester's operator is obliged to follow up the course of stump treatment. To make this job easier, a dye marker is added to the spray solution, and there is a manual measuring device, which shows to what extent the stump surface is covered with the solution. As provided by quality requirements, about 85% of the stump surface should be covered with the solution. As the dye marker biologically disintegrates in three days, the job supervisor is supposed to check the quality of stump treatment during this time span (2014 Verdera). This is the second level of control. A special electronic form has been worked out in this project to facilitate decision-making regarding stump treatment quality control. The readings of the measuring device are entered into this form and a mathematical algorithm (based on excel) incorporated therein calculates an average for the proportion of stump surface treated.

The third level of control, following a method worked out in this project at the Latvian State Forest Research Institute 'Silava', goes with collecting the wood samples from treated stumps and laboratory analyses to determine the occurrence *P. gigantea* in these samples. Normally, the mentioned control is done once a year in cases we doubt the job quality of one or another service provider. Sampling is done not earlier than 30 days after the Rotstop application.

5 to 20 stumps are randomly chosen for sampling, depending on the stand composition and the stump mean diameter. A disk about 5 cm thick is sawn off the stump surface, leaving the disk on-site. For the needs of analyses another disk is sawn off. The wooden disks thus prepared are accordingly labelled and placed into plastic bags. The laboratory analyses are done in one or two days after preparing the disks. In the laboratory the disks are debarked and washed under tap water using a brush. After drying the disks are placed in plastic bags and incubated for 5 to 7 days. Incubation results in the signs of *P. gigantea* presence that appear as orange brown colour on the disk surface. A wood sample, 2 – 3 cm wide and 7 – 10 mm deep, is taken using a flame-sterilized chisel from the disk surface at the spot where the *P. gigantea* staining is the biggest. Then rectangular-shaped small pieces of wood are cut out by using a sterile scalpel and placed on sterile Petri dish containing malt extract agar medium. The dish is placed in a thermostat and kept there for about two weeks at the ambient temperature +20 °C till the fungus monoculture is ready for further use. In order to determine whether the *P. gigantea* found on the wooden disk belongs to the Rotstop genotype, tiny pieces (size about 2 × 4 mm) of its mycelium are placed on the Petri dish with malt extract agar medium using a sterile dropper. Then a piece of agar with the tester's culture is placed on the said dish some 1.5 – 2 cm away from the culture to be tested. The tester's culture is derived from the Rotstop preparation, putting a small amount of it on the malt extract agar medium. Similarity between the culture to be tested and the Rotstop genotype is evaluated within 3 – 4 weeks by observing the changes in the tester's culture and an emergence of demarcation or confrontation lines between the two cultures. Emergence of demarcation line is a proof that the respective cultures belong to different genotypes (Stenlid, 1985). In this experiment more than 200 wooden disks were analysed.

Results and Discussion

Use of the Rotstop in forestry practices

Stumps should be treated by Rotstop preparations in warm weather when the air temperature is above 5 °C and *H. annosum* fruiting bodies intensively sporulate. In Latvian conditions the sporulation is found to be most active from April till November. For example, you can see dynamics of sporulation of *H. annosum* fruiting bodies in the year 2012, in Figure 1. (Brūna, unpublished data).

In 2006, the LVM as a manager of state-owned forests started testing the methods of Rotstop application and worked out regulatory documents for its application and efficiency control. By 2007 the procedure of registering the Rotstop preparations in Latvia had been completed. In 2008, before the Rotstop implementation in forestry practices, a training session, involving the experts (partners from approbation experiment) of the Latvian State Forest Research Institute 'Silava', was organized for the LVM staff and its cooperation partners, training 400 persons in total. The implementation of Rotstop methods was a step-by-step process, first applying them in thinning to some 1,200 ha (2008). The aim was to increase the application of this method so as to fully cover the required volume of thinnings in conifer stands in warm weather. Because of the 2009 economic crisis, the Rotstop use was discontinued and resumed again in 2010 with the forest areas thus treated increasing steadily since then (Fig. 2).

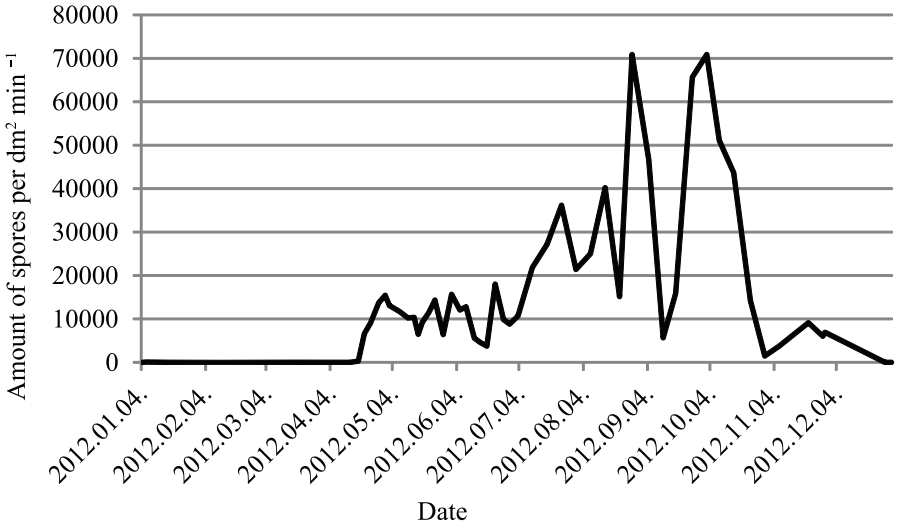

Figure 1. Sporulation intensity of H. annosum fruiting bodies in the year 2012.

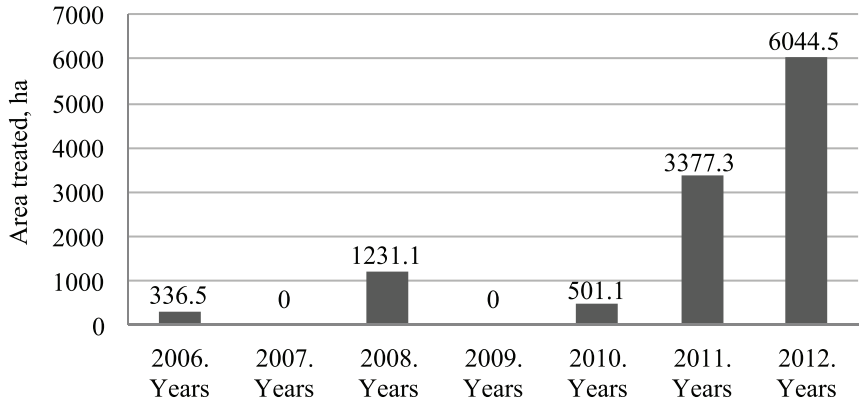

Figure 2. Dynamics of the Rotstop application in LVM forests.

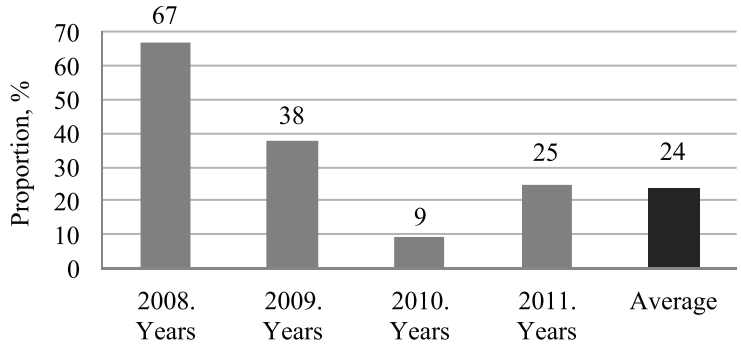

Figure 3. Proportion (%) of cutting area with improper treatment by Rotstop (the cutting areas where there was a strong doubt as to the quality of treatment are included).

Quality control of the jobs done

The LVM employees and service providers use the Rotstop preparations for reduction of the spread of root rot and carry out the controls following the methods described in chapter 'Quality control of stump treatment'. The related analyses are done on an annual basis at the Latvian State Forest Research Institute 'Silava'. For the past three years no *P. gigantea* genotype derived from the Rotstop preparation has been detected on the average in 25% of the stumpwood samples analysed (Fig. 3). This indicator does not reflect the overall situation with the use of Rotstop at the LVM, but only the situation in particular cutting areas as the control refers only to those sites where we reasonably doubted the quality of treatment.

When evaluating the results of 2011 analyses in greater detail, *P. gigantea* is found more often in pinewood, taking up a higher proportion of the stump surface (Table 1). In pinewood *P. gigantea* occupies from 1.04 to 98.00% of the stump surface, while for the wood of spruce this indicator is 0.08 – 75.00%, respectively. It confirms the conclusion made in other studies that *P. gigantea* colonizes pinewood more intensively even in case of improper stump treatment (Thor, 2005), which may be explained by the biology of *P. gigantea*, normally colonizing pinewood (Lipponen, 1991; Korhonen, 2001). It implies that the quality of stump treatment is decisive when dealing with spruce (Thor, 2005).

In analyses of the 2011 samples for the occurrence of natural infection by *P. gigantea* and that of the Rotstop isolate, no differences were detected between the samples of pine and spruce. It implies that natural infection by *P. gigantea* competes with artificially provoked one by stump treatment with Rotstop. This is a positive sign, indicating that the nature itself provides significant natural competition to *H. annosum*, which is likely to appear after thinning. A number of factors like site location, forest type, air temperature, ground cover vegetation, moisture, season of the year, competition of other fungi, and *H. annosum* in particular, affect the development of *P. gigantea*. If *H. annosum* infection background in the stand is high, the development of *P. gigantea* is limited (Berglund and Rönnberg, 2004; Berglund et al., 2005).

Table 1

Occurrence of *Phlebiopsis gigantea* and area occupied by this fungus on the stumps analysed in 2011

Tree species	Number of stumps with *P. gigantea*	Proportion of analyzed stumps with *P. gigantea*, %*	Average area of *P. gigantea* on stump disks, % of the total area (±standard error)
Pine	93	85	59.27±3.33
Spruce	200	75	9.24±1.01

*stumps with both Rotstop and natural *P. gigantea.*

The proportion between the natural *P. gigantea* and Rotstop strain in the isolates analysed was 38% and 62% for pine, and 36% and 64% for spruce. According to the studies done in Sweden, in rot control the efficacy of local *P. gigantea* strains may be higher than that of Rotstop ones (Berglund et al., 2005). That is why in a number of countries research is under way to find efficient local *P. gigantea* strain suitable for stump treatment against root rots. Similar research has also been done in Latvia, and the efficacy of *P. gigantea* isolate of Latvian origin was not lower than that of Finnish preparations (Kenigsvalde et al., 2011). Regardless of a popular belief that natural *P. gigantea* cannot protect the stumps from the infection by *H. annosum* basidiospores (Drenkhan et al., 2008; Rönnberg, 2006), our results confirm the natural *P. gigantea* to be efficient for suppressing the development of *H. annosum* especially in stumps of small-dimension pines (Gaitnieks, unpublished data). A task for the future is to identify the factors favouring the development of natural *P. gigantea.*

Conclusions

1. Following the Scandinavian experience and the test results in Latvia the Rotstop preparation, containing *P. gigantea* spores, may be used for controlling *H. annosum.*
2. When analysing stumpwood samples from the cutting areas where there was reasonable doubt of improper Rotstop application, no *P. gigantea* genotype, existing in the Rotstop preparation, was detected on the average in 25% of the stumpwood samples.
3. Analyses of stumpwood samples confirm a conclusion made in other studies that *P. gigantea* colonize pinewood more intensively even in case of improper stump treatment by the Rotstop preparation.

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References

1. Arhipova N., Donis J., Gaitnieks T., Liepa I. (2010) Sakņu un stumbra trupi izraisošo sēņu sastopamība egļu audzēs – lapu koku piemistrojuma ietekme uz *Heterobasidion* spp. izplatību (The root and the stem rot induce fungi incidence in spruce stands- the deciduous admixture impact on *Heterobasidion* spp. distribution). *Mežzinātne* 22 (55), 70 – 87. lpp. (in Latvian).
2. Asiegbu F.O., Adomas A., Stenlid J. (2005) Conifer root and butt rot caused by *Heterobasidion annosum* (Fr.) Bref. s.l. *Molecular Plant Pathology*, Volume 6, Issue 4, pp. 395 – 409.
3. Bendz-Hellgren M., Brandtberg P.-O., Johansson M., Swedjemark G., Stenlid J. (1999) Growth rate of *Heterobasidion annosum* in *Picea abies* established on forest land and arable land. *Scandinavian Journal of Forest Research*, Volume 14, pp. 402 – 407.
4. Berglund M., Rönnberg J. (2004) Effectiveness of treatment of Norway spruce stumps with *Phlebiopsis gigantea* at different rates of coverage for the control of *Heterobasidion*. *Forest Pathology*, 34, pp. 233 – 243.
5. Berglund M., Rönnberg J., Holmer L., Stenlid J. (2005) Comparison of five strains of *Phlebiobsis gigantea* and two *Trichoderma* formulations for treatment against natural *Heterobasidion* spore infections on Norway spruce stumps. *Scandinavian Journal of Forest Research*, 20 (1), pp. 12 – 17.

6. Cleary M.R., Arhipova N., Morrison D.J., Thomsen I.M., Sturrock R.N., Vasaitis R., Gaitnieks T., Stenlid J. (2013) Stump removal to control root disease in Canada and Scandinavia: a synthesis of results from long-term trials. *Forest Ecology and Management*, 290, pp. 5 – 14.
7. Drenkhan T., Hanso S., Hanso M. (2008) Effect of the stump treatment with *Phlebiopsis gigantea* against *Heterobasidion* root rot in Estonia. *Baltic Forestry*, 14(1), pp. 16 – 25.
8. Epstein A.H. (1978) Root Graft Transmissions of Tree Pathogens. *Annual Review of Phytopathology*, Volume 16, pp. 181 – 192.
9. Hodges C.S. (1969) Modes of infection and spread of *Fomes annosus*. *Annual Review of Phytopathology*, Volume 7, pp. 247 – 266.
10. Kenigsvalde K., Donis J., Korhonen K., Gaitnieks T. (2011) *Phlebiopsis gigantea* skujkoku celmu bioloģiskajā aizsardzībā pret *Heterobasidion annosum* s.l. izraisīto sakņu trupi - literatūras apskats (Biological control of *Heterobasidion* root rot of coniferous stumps by *Phlebiopsis gigantea* – literature review). *Mežzinātne*, 23(56), 25 – 40. lpp. (in Latvian).
11. Korhonen K. (2001) Simulated stump treatment experiments for monitoring the efficacy of *Phlebiopsis gigantea* against *Heterobasidion annosum*. In: Laflamme G., Bérubé J.A., Bussières G. (eds). *Proceedings of 10th IUFRO Conference on Root and Butt Rots*. Canadian Forest Service, pp. 206 – 210.
12. Lipponen K. (1991) Juurikäävän kantotartunta ja sen torjunta enshiharvennusmetsiköissä (Stump infection by *Heterobasidion annosum* and its control in stands at the first thinning stage). *Folia Forestalia*, 770, p. 12. (in Finnish with English summary).
13. Valsts meža dienests (State Forest Service) (2014) Meža apsaimniekošana (Forest management). Available at: http://www.vmd.gov.lv./valsts-meza-dienests/statiskas-lapas/-meza-apsaimniekosana-?nid=870, 10 March 2014.
14. Müller M.M., Heinonen J., Korhonen K. (2007) Occurrence of *Heterobasidion* basidiocarps on cull pieces of Norway spruce left on cutting areas and in mature spruce stands. *Forest Pathology*, Volume 37, pp. 374 – 384.
15. Piri T. (1996) The spreading of the S-type of *Heterobasidion annosum* from Norway spruce stumps to the subsequent tree stand. *European Journal of Forest Pathology*, Volume 26, pp. 193 – 204.
16. Piri T., Korhonen K. (2001) Infection of advance regeneration of Norway spruce by *Heterobasidion parviporum*. *Canadian Journal of Forest Research*, Volume 31, pp. 937 – 941.
17. Rishbeth J. (1951) Observations on the Biology of *Fomes annosus*, with Particular Reference to East Anglian Plantations: II. Spore Production, Stump Infection, and Saprophytic Activity in Stumps. *Annals of Botany*, Volume 15, Issue 1, pp. 1 – 22.
18. Rotstop (2014) Verdera. Available at: http://verdera.fi/en/products/forestry/rotstop/, 25 May 2014.
19. Rönnberg J. (2000) Logging operation damage to roots of clear-felled *Picea abies* and subsequent spore infection by *Heterobasidion annosum*. *Silva Fennica*, Volume 34, Issue 1, pp. 29 – 36.
20. Rönnberg J., Sidorov E., Petrylaite E. (2006) Efficacy of different concentrations of Rotstop® and Rostop® S and imperfect coverage of Rotstop® S against *Heterobasidion* spp. spore infections on Norway spruce stumps. *Forest Pathology*, Volume 36, pp. 422 – 433.
21. Schütt P., Schuck H.J. in cooperation with Lauten schlarger K., Prestle W., Stimm B. (1979) *Fomes annosus* sporocarps - their abundance on decayed logs left in the forest. *European Journal of Forest Pathology*, Volume 9, pp. 57 – 61.
22. Stenlid J. (1985) Population structure of *Heterobasidion annosum* as determined by somatic incompatibility, sexual incompatibility, and isoenzyme patterns. *Canadian Journal of Botany*, Volume 63, Issue 12, pp. 2268 – 2273.
23. Stenlid J., Wästerlund I. (1986) Estimating the frequency of stem rot in *Picea abies* using an increment borer. *Scandinavian Journal of Forest Research*, Volume 1, pp. 303 – 308.
24. Stivriņa B., Kenigsvalde K., Korhonen K., Gaitnieks T. (2010) Lielu dimensiju ciršanas atlieku nozīme *Heterobasidion* sp. infekcijas izplatībā (The large dimension cutting residues role in *Heterobasidion* spp. infection prevalence). *Mežzinātne*, 22(55), 88 – 102. lpp. (in Latvian).
25. Thor M. (2005) *Heterobasidion* root rot in Norway spruce: Modelling incidence, control efficacy and economic consequences in Swedish forestry. Doctor's dissertation. Swedish University of Agricultural Sciences, Uppsala, pp. 8 – 39.
26. Vasaitis R., Stenlid J., Thomsen I.M., Barklund P., Dahlberg A. (2008) Stump removal to control root rot in forest stands. A literature study. *Silva Fennica*, 42, pp. 457 – 483.
27. Woodward S., Stenlid J., Karjalainen R., Hüttermann A. (1998) *Heterobasidion annosum: biology, ecology, impact and control.* CAB International, Wallingford, UK, pp. 589.

COLOUR STABILITY OF THERMALLY MODIFIED HARDWOOD

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Abstract
Thermal wood modification has been intensively studied in the recent decades because of the possibility to produce wood with improved biodurability and dimensional stability without use of harmful chemicals. Beside altered physical characteristics, wood colour is changed to lighter or darker brown as a result of thermal treatment. Growth of interest in thermal wood treatment has stimulated numerous researches concerned with discoloration of thermally modified wood which is subjected to light exposure. The objective of this study was to evaluate the colour stability of thermally modified hardwood during storage in the dark where wood discolouration is not photoinduced but rather a result of oxidative ageing. Three thermally modified hardwood species – aspen (*Populus tremula* L.), alder (*Alnus incana* Moench), birch (*Betula pendula* Roth.), where investigated. Wood discoloration was monitored by spectrophotometrical measurements of reflectance spectra and chromaticity parameter calculations using CIELAB colour system where L* is the lightness, and a* and b* are the chromatic coordinates. The colour stability of thermally modified wood as well as of untreated wood of the same species was examined by means of assessment of the colour parameter changes (ΔL*, Δa*, Δb*, ΔEab). All wood specimens under study discoloured during the experiment, but the colour change did not exceed two units that is common and accepted for wood products. Untreated and thermally modified wood showed different trends of discoloration during storage in the dark. The final colour changes that were fixed at the end of the experiment were greater for the thermally treated wood.
Key words: hardwood, thermal modification, colour stability.

Introduction

Thermal wood treatment is a wood modification method that enhances the dimensional stability, hydrophobicity and biodurability of wood without using any harmful chemicals (Ates et al.; 2009, Severo et al., 2012, Andersons et al., 2013). The production of thermally modified wood has been increasing during the last decades (Sandberg et al., 2013). The thermal treatment always results in darkening of wood, which is often attributed to the formation of coloured degradation products from hemicelluloses and extractive compounds (Sundqvist and Moren, 2002; Windeisen and Wegener, 2008) and oxidation products such as the quinones-like substances (Bekhta and Niemz, 2003; Gonzales-Pena and Hale, 2009). The brown colour of thermally modified wood has often been regarded as an additional advantage of it. Sometimes heat treatment is purposely used to change the aesthetic properties of wood and thermally modified wood is used as a substitute for some tropical hardwoods (Miklecic et al., 2011). Wood colour is one of the most valuable characteristics for its use as a decorative material, as it is an important aesthetic component. The colour of solid material is a composite property, the value of which is related to its basic chemical composition. The absorption of visible light for a material is characteristic and is caused by molecules called chromophores, which are able to absorb certain wavelengths region of the visible light. For decorative end-use, the colour stability of wood is a significant prerequisite. Colour stability is usually examined by studying the rate and amount of discoloration that wood surface undergoes when exposed to light. In order to study colour changes, colour has to be measured in an objective way. Most wood colour studies quantify the colour by the CIELAB method developed by the Commision Internationale de l'Eclairage (CIE) (International Commission on Illumination). The CIEALB system is a colour model, which describes each colour by a three-dimensional coordinate system (Pauler, 2002). Numerous studies have been made to establish the effect of light on wood and cellulosic materials. Mainly ultra-violet light (300 to 400 nm) and, to a smaller extension, also the shorter wavelength region of the visible light (400 to 500 nm) are known to be the main reason for the discolouration and degradation of wood surface exposed to light (Kataoka et al., 2007). It has been discovered that the colour of thermally modified wood also is not light resistant and discolours under light exposure (Yildiz et al., 2011). It has also been established, that due to changed chemical structure, the photodiscolouration of thermally modified wood varies from that of untreated wood (Ayadi et al., 2003; Ahaji et al., 2009). However, most of the investigations have been concerned to photoinduced discoloration of thermally modified wood. The objective of this study was to evaluate the colour stability of thermally modified hardwood, which was stored in the dark where wood discolouration is not photoinduced, but it is rather the result of oxidative ageing. Three thermally modified hardwood species – aspen (*Populus tremula* L.), gray alder (*Alnus incana* Moench) and birch (*Betula pendula* Roth.), were studied.

Materials and Methods

Three hardwood species were used in this study - aspen (*Populus tremula* L.), gray alder (*Alnus incana* Moench) and birch (*Betula pendula* Roth.). Wood boards measuring 1000 × 100 × 25 mm were thermally modified in a laboratory experimental wood modification device produced by Wood Treatment Technology (WTT). The modification was carried out in a water vapour medium under elevated pressure (0.6 MPa) at 170 °C for one hour. After modification boards were conditioned at 20 °C and 65% relative humidity for a month. The conditioned boards were cut into specimens measuring 70 × 50 × 20 mm and the surfaces of the specimens were planned. In the same way, specimens from untreated boards of the same species were prepared.

Wood colour and reflectance spectra measurements were carried out using a Minolta CM-2500d spectrophotometer equipped with an integrating sphere, with standard light source D65 at an observation angle of 10 ºC, the diameter of the light spot was 8 mm. The scanning wavelength was from 360 to 740 nm. The reflectance spectra were recorded against a white optical standard. Each reflectance spectrum was the average of three measurements. The spectrum of the reflected light, collected at 10 nm intervals were converted into the CIELAB colour system, where parameter L* describes the lightness (from zero – black to 100 – white) and parameters a* and b* describe the chromaticity coordinates on the green-red and yellow-blue axis, respectively. From the L*, a*, b* parameter values obtained, the differences of the colour parameters ΔL*, Δa*, Δb* and the total colour changes ΔEab were calculated. These values have often been used to trace colour modifications during modification and weathering of woods (Ayadi et al., 2003; Miklecic et al., 2011; Buchelt et al., 2012). The equation used for the colour changes ΔEab calculation was as follows:

$$\Delta E_{ab} = \left(\left(\Delta L^* \right)^2 + \left(\Delta a^* \right)^2 + \left(\Delta b^* \right)^2 \right)^{\frac{1}{2}}, \quad (1)$$

where: ΔL*, Δa*, Δb* are the changes between the initial and the interval values.

Considering the inherent colour inhomogenity of wood, the measurements were always performed on the same three marked locations and colour of each specimen was described by the arithmetic mean of the three measurements.

Initial colour measurements were performed 24 hours after the specimens were planed. Throughout the experiment the specimens were kept in dark at ambient room temperature and relative humidity and withdrawn only to make colour measurements. Colour measurements for all specimens were made at intervals throughout the test period. The total length of the experiment was 270 days, which was enough time for the colour changes of the thermally modified wood to reach the plateau.

Results and Discussion

Reflectance spectra of untreated wood of the three studied species noticeably differed from each other (Fig. 1).

The spectra varied both by reflectance rate and pattern. This is in accordance with the CIELAB colour parameter values recorded in the Table 1. The data showed that the three wood species differed from one another by their colour parameter values. The lightness parameter L* and redness parameter a* values showed the greater differences among species. Untreated aspen wood was characterized by the highest reflectance rate throughout the entire visible light spectrum (Fig. 1) as well as the highest lightness and the lowest chromaticity parameter a* and b* values (Table 1). On the contrary, alder wood had the lowest reflectance in the whole range of the visible

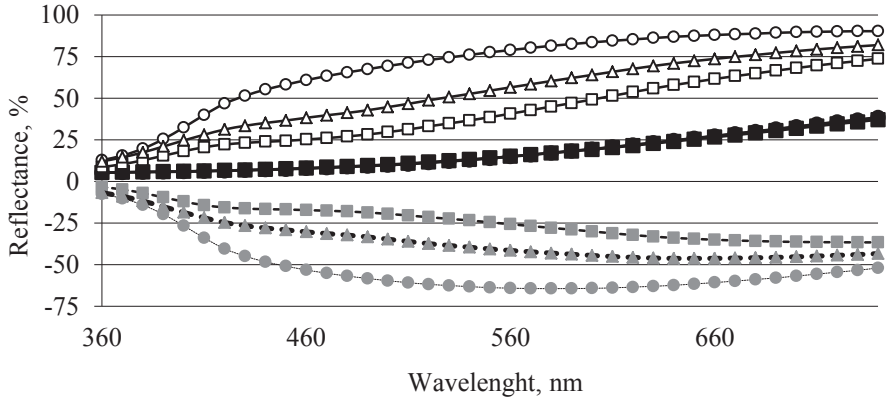

Figure 1. Reflectance spectra and reflectance difference spectra of untreated and thermally modified (170 °C) aspen, alder and birch wood: black symbols – thermally modified wood; white symbols – untreated wood; gray symbols – reflectance difference; ○ (circles) – aspen; □ (squares) – alder; D (triangles) - birch.

Table 1

Colour parameters and colour changes of untreated and thermally modified (170 °C) aspen, alder and birch wood

Type of sample		L*	a*	b*	DL*	Da*	Db*	DEab
Thermally modified	Aspen	45.0 (2.2)	10.6 (0.3)	20.7 (2.3)	-45.2	9.7	4.2	46.5
	Alder	45.2 (0.6)	9.5 (0.3)	20.1 (0.2)	-24.0	-0.6	-1.1	24.0
	Birch	45.2 (2.1)	10.5 (0.3)	20.4 (1.3)	-33.6	4.4	0.2	33.9
Untreated	Aspen	90.2 (1.4)	0.9 (0.7)	16.5 (1.7)	´	´	´	´
	Alder	69.2 (1.3)	10.1 (0.3)	21.2 (0.8)	´	´	´	´
	Birch	78.8 (3.1)	6.1 (1.1)	20.2 (1.4)	´	´	´	´

* Values in parenthesis are standard deviations

light spectrum as well as the lowest lightness and the highest chromaticity parameter values.

Thermal modification induced noticeable changes in wood colour of all investigated species and wood with dark brown colour was produced. During the thermal modification, the reflectance of wood obviously diminished in the whole range of the visible light spectrum for all wood species (Fig. 1). It implies that components absorbing visible light were formed during thermal modification. Contrary to untreated wood, the reflectance spectra of the thermally modified wood for all the species were nearly equal. The decrease of the reflectance rates was consistent with the changes in lightness ΔL* (Table 1) which went towards darkening (negative lightness difference ΔL* values) for the all species but in different magnitude. The changes in the chromaticity coordinates a* and b* did not follow one common pattern for the three wood species. For aspen and birch wood both coordinates a* and b* increased and bigger changes occurred to redness coordinate a*.

Inversely, chromaticity coordinates of alder wood decreased and the bigger change occurred to yellowness coordinate b*. The observed differences are in accordance with findings of T. Schnabel et al. (2007) and B.M. Esteves et al. (2008) who have stated, that different wood species undergo dissimilar colour changes during heat treatment even under similar modification conditions.

The reflectance difference spectra (Fig. 1) show that the reflectance decreased in the whole range of visible light for all the wood species as a result of the thermal treatment. There was no distinct maximum on the reflectance difference spectra. This finding indicates that a variety of chromophores with different characteristic absorption wavelengths was produced during thermal modification.

Colour changes during storage in the dark are mainly related to readily oxidizable chemical compounds on the wood surface that undergo oxidative reactions resulting in an alteration of the chromophoric groups. During the experiment, all the studied specimens discoloured but at different rate and magnitude (Fig. 2).

Untreated alder and birch wood showed similar pattern of discolouration. After rapid initial colour

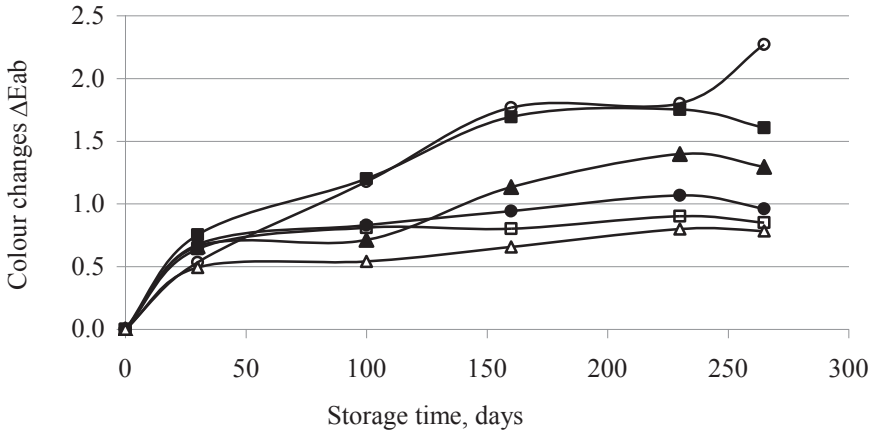

Figure 2. Colour changes ΔEab of thermally modified (170 °C) and untreated aspen, alder and birch wood as a function of storage time in the dark: filled symbols – thermally modified wood; open symbols – untreated wood; ○ (circles) – aspen; □ (squares) – alder; D (triangles) – birch.

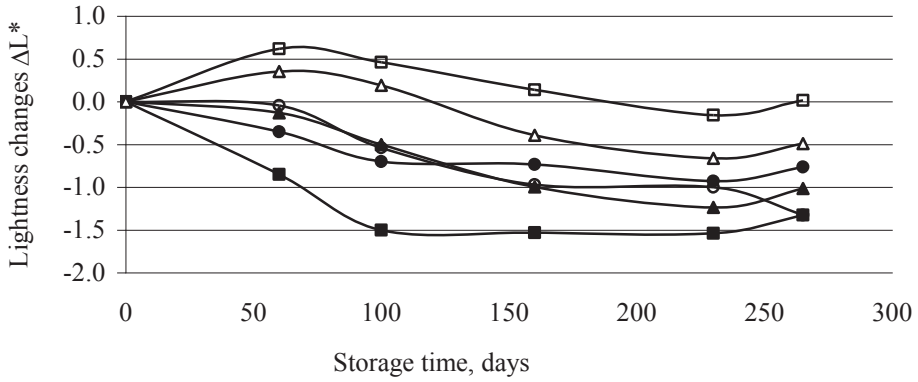

Figure 3. Lightness changes DL* of thermally modified (170 °C) and untreated aspen, alder and birch wood as a function of storage time in the dark: filled symbols – thermally modified wood; open symbols – untreated wood; ○ (circles) – aspen; □ (squares) – alder; D (triangles) – birch.

changes during the first 30 days, the discoloration subsided and wood attained almost a constant colour change DEab values. After storage for 270 days in the dark, untreated alder and birch wood showed the minor colour changes ΔEab, which were even less than one unit. Thermally modified aspen wood also showed colour changes of almost the same value. The rapid initial discolouration after planning can infer that some chemically reactive substances with chromophoric groups that do not need any photoexcitation to be oxidized, were exposed on the wood surface after wood processing. Untreated aspen wood was the most unstable one with respect to discoloration during storage in the dark. At the end of the experiment, the colour change ΔEab of untreated aspen wood had reached value of 2.3 units and there was no evidence that the process of discolouration had stopped. Aspen wood varied from the other untreated woods also by the pattern of colour changes. Untreated aspen wood darkened throughout the entire experiment (Fig. 3) and by this differed from the other untreated specimens, which became lighter at first.

The reason of such a different behaviour of the three studied hardwoods could be the differences in their chemical composition, mainly the difference in content and composition of extractives. It has been established that some extractives have an antioxidant capacity and play important role in colour evolution and change of wood (Ahaji et al., 2009; Varga and Van der Zee, 2008).

The colour changes of all thermally modified wood species (Fig. 2) increased up to approximately 220 days and then a slight decrease can be seen at the end of the experiment. The pattern of discolouration of the thermally modified wood can be related to the lightness changes ΔL* (Fig. 3). The correlation between the trends of colour change ΔEab and lightness change ΔL* for thermally modified wood agrees with the finding that the major contributor to the colour changes, in the case of thermally

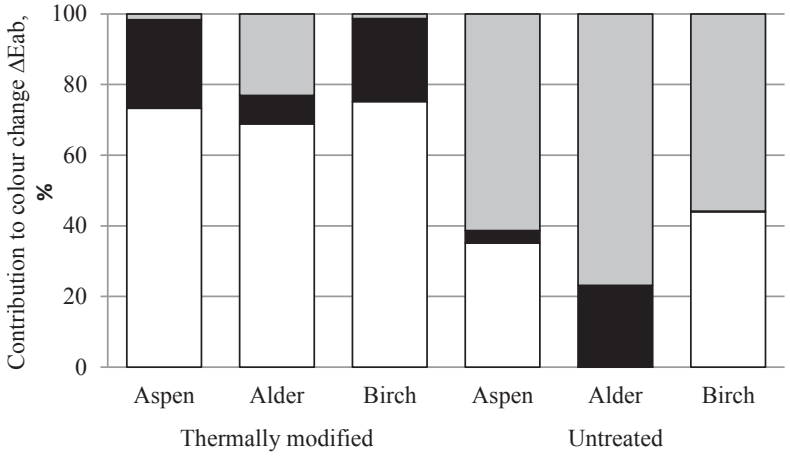

Figure 4. Contribution of each color parameter changes (DL*, Da*, Db*) into total color changes DEab after storage in dark for 270 days for untreated and thermally modified (170 °C) aspen, alder and birch wood: white - ΔL*; black - Δa*; grey - Δb*.

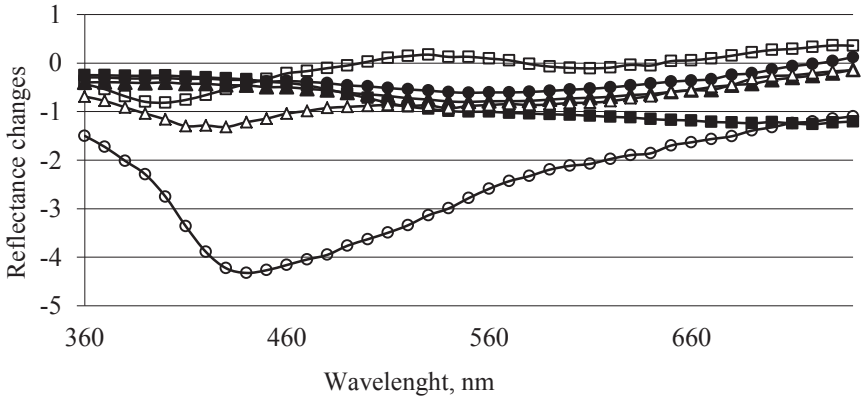

Figure 5. Reflectance difference spectra of untreated and thermally modified (170 °C) aspen, alder and birch wood after storage in the dark for 270 days: filled symbols – thermally modified wood; open symbols – untreated wood; ○ (circles) – aspen; □ (squares) – alder; D (triangles) – birch.

modified wood, were the lightness change ΔL* values (Fig. 4).

For thermally modified wood, the lightness change DL* values contributed more than 70% to the total colour changes DEab. In the case of untreated wood, the bigger contributors were chromaticity parameters.

Alternating directions of the lightness changes ΔL* were observed for all the specimens during the experiment. As it was mentioned above, untreated woods showed different patterns concerning the lightness changes. Unlike it, common trend for thermally modified specimens was observed. Colour of all the thermally modified specimens became darker throughout the entire experiment. It was indicated by decreasing values of lightness changes DL* (Fig. 3). The results of final measurements showed that the darkening had stopped and even a tendency of slight lightening can be noticed at the end of the experiment.

The results showed that the pattern of colour changes due to oxidative aging differed between the untreated and thermally modified specimens and also among untreated wood species under study. It was also supported by reflectance difference spectra for the reflectance changes at the end of the experiment (Fig. 5).

It can be seen that at the end of the experiment, reflectance of untreated aspen wood had considerably decreased in comparison with other examined specimens. Pronounced band of reflectance difference had appeared at a wavelength region 380 to 560 nm. It indicates that chromophoric groups were formed with characteristic absorbance in the shorter wavelength region of the visible light. Reflectance reduction in the same wavelength region, although on a noticeably smaller scale, can be observed also for untreated alder and birch wood. The increase in absorption of violet, blue and green light (400 – 520 nm) agrees with the finding that the yellowness parameter changes Δb* contributed more than 50% into the total colour change ΔEab of untreated wood (Fig. 4).

At the end of the 270 days experiment, the final colour changes were greater for the thermally modified wood than for the untreated wood with the exception of untreated aspen wood. This is in contrast to findings that the colour of thermally modified wood is more stable than that of untreated wood when exposed to ultraviolet light (Rosu et al., 2010; Miklecic et al., 2011). Obviously, thermally modified wood contains relatively more components with chromophoric groups that can react with oxygen without any photoexcitation.

After storage in the dark for 270 days, the colour changes ΔEab were in the range between one and two units for all the modified wood species. Colour differences of the magnitude one to two units are absolutely common and accepted for wood products (Buchelt and Wagenfuhr, 2012). Such differences are considered as an observable colour difference, which is barely perceptible. This indicates that thermally modified wood inhere stable colour when not exposed to light.

Conclusions

1. Freshly planed surfaces of both untreated and thermally modified aspen, alder and birch wood discolour during storage in the dark. The colour changes DEab of thermally modified aspen, birch and alder wood do not exceed two units, which is common and acceptable for wood products.
2. Untreated and thermally modified wood shows different trends of discoloration during storage in the dark. For thermally treated wood, the dominant changes occur with the lightness parameter L* values while the yellowness parameter b* is most changed in untreated wood.

3. The colour changes after storage for 270 days in the dark were greater for the thermally treated wood. It indicates that thermally modified wood contains relatively more components with chromophoric groups that can react with oxygen without any photoexcitation.

References

1. Ahaji A., Diouf P.N., Aloui F., Elbakali I., Perrin D., Merlin A., George B. (2009) Influence of heat treatment on antioxidant properties and colour stability of beech and spruce wood and their extractives. *Wood Science and Technology*, 43, pp. 69 – 83.
2. Andersons B., Andersone I., Irbe I., Chirkova J., Cirule D., Biziks V., Grinins J., Sansonetti H. (2013) New products from deciduous wood by one-stage hydrothermal modification, In: Berti S. (ed) *The 4th International Scientific Conference on Hardwood Processing 2013,* CNR IVALSA, Florence, Italy, pp. 220 – 226.
3. Ates S., Akyildiz M.H., Ozdemir H. (2009) Effects of heat treatment on Calabrian pine (*Pinus brutia* Ten.) wood. *BioResources*, 4(3), pp. 1032 – 1043.
4. Ayadi N., Lejeune F., Charrier F., Charrier B., Merlin A. (2003) Color stability of heat-treated wood during artificial weathering. *Holz als Roh- und Werkstoff*, 61, pp. 221 – 226.
5. Bekhta P., Niemz P. (2003) Effect of high temperature on the change in color, dimensional stability and mechanical properties of spruce wood. *Holzforschung,* 57, pp. 539 – 546.
6. Buchelt B., Wagenfuhr A. (2012) Evaluation of colour differences on wood surfaces, *European Journal of Wood and Wood Products*, 70, pp. 389 – 391.
7. Esteves B.M., Domingos I.J., Pereira H.M. (2008) Pine wood modification by heat treatment in air. *BioResuorces*, 3(1), pp. 142 – 154.
8. Gonzales-Pena M.M., Hale M.D.C. (2009) Colour in thermally modified wood of beech, Norway spruce and Scots pine. Part1: Colour evaluation and colour changes. *Holzforschung,* 63, pp. 385 – 393.
9. Kataoka Y., Kiguchi M., Williams R.S., Evans P.D. (2007) Violet light causes photodegradation of wood beyond the zone affected by ultraviolet radiation. *Holzforschung,* 61, pp. 23 – 27.
10. Miklecic J., Jirouš-Rajkovic V., Antonovic A., Španic N. (2011) Discolouration of thermally modified wood during simulated indoor sunlight exposure. *BioResources,* 6(1), pp. 434 – 446.
11. Pauler N. (2002) *Papere optics*, AB Lorentzen and Wettre, Ostervala, Sweden, 93 p.
12. Rosu D., Teace C.A., Bodirlau R., Rosu L. (2010) FTIR and color of the modified wood as a result of artificial light irradiation. *Journal of Photochemistry and Photobiology B: Biology,* 99, pp. 144 – 149.
13. Sandberg D., Haller P., Navi P. (2013) Thermo-hydro and Thermo-hydro-mechanical wood processing: An opportunity for future environmentally friendly wood products. *Wood Material Science and engineering,* 8(1), pp. 64 – 88.
14. Schnabel T., Zimmer B., Petutshnigg A.J., Schonberger S. (2007) An approach to classify thermally modified hardwood by color. *Forest Products Journal,* 57(9), pp. 105 – 110.
15. Severo E.T.D., Calonego F.W., Sansigolo C.A. (2012) Physical and chemical changes in juvenile and mature woods of *Pinus elliotti var. elliotti* by thermal modification. *European Journal of Wood and Wood Products*, 70, pp. 741 – 747.
16. Sundqvist B., Moren T. (2002) The influence of wood polymers and extractives on wood colour induced by hydrothermal treatment, *Holz als Roh- und Werkstoff*, 60, pp. 375 – 376.
17. Varga D., Van der Zee M.E. (2008) Influence of steaming on selected wood properties of four hardwood species. *Holz als Roh- und Werkstoff*, 66, pp. 11 – 18.
18. Windeisen E., Wegener G. (2008) Behavior of lignin during thermal treatments of wood. *Industrial Crops and Products*, 27, pp. 157 – 162.
19. Yildiz S., Yildiz U.C., Tomak E.D. (2011) The effects of natural weathering on the properties of heat-treated alder wood. *BioResources*, 6(3), pp. 2504 – 2521.

EVALUATION OF THERMAL PROPERTIES OF WOOD BASED COMPOSITE PANEL WALLS

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Abstract
Invention of light weight cellular wood material (CWM) with a trade mark of Dendrolight is one of the most important innovations in wood industry of the last decade. Currently CWM has been used as core material for sandwich-panels. These three layer panels are used in furniture industry and have wide non-structural applications. The aim of the research was to define the thermal properties of CWM and evaluate various wall envelopes where solid wood cellular material is used. There were 4 specimens of cellular wood material manufactured with nominal dimensions thickness 120 mm, length and with 600 mm to determine thermal conductivity and thermal transmittance according to standard EN 12667:2002. The specimens were manufactured of four layer 112 mm thick Scots pine (*Pinus sylvestris* L.) CWM double faced with 4 mm thick high-density fiberboard (HDF). Adhesive used in the bonding process was polivinilacetate Cascol 3353. Each direction (parallel, perpendicular) was represented by two specimens. Common procedure to evaluate the energy efficiency of building envelope is to calculate thermal transmittance in static conditions. The influence of the cellular material orientation to its thermal properties was investigated. Coefficient of thermal conductivity was determined for both material directions of CWM (l_0=0.0977 $W \cdot m^{-1} \cdot K^{-1}$ l_{90}=0.148 $W \cdot m^{-1} \cdot K^{-1}$), combining the test method of EN 12667:2002 and calculation method of standard EN 6946:2008. To calculate thermal transmittance of various wall envelopes calculation software in JavaScript environment was created. Various compositions of external walls were assessed, thermal transmittance of these structures were calculated according to standard EN 6946:2008.
Key words: light weight panels; cellular wood; thermal conductivity; thermal transmittance.

Introduction

The efficiency of building material is question that should be evaluated through various aspects of its lifecycle. The material should be energy, resource and labor efficient in production, transportation, assembling, exploitation and recycling processes. Several researchers (Voth, 2009; Skuratov, 2010) are looking for new construction materials and light - weight structural panels for efficient wood buildings. One possibility to utilize full potential of structural material is to create a sandwich panel. Efficiency studies and guidelines for effective sandwich panel structural design are outlined by J. Pflug et al., (2003). With rising demand for energy efficient homes, thermal properties of building materials and structures are those that are investigated most when the choice between the alternative construction materials are made. Thermal conductivity of material in most cases is related to the density of the material. One way how density of material can be reduced and thermal resistance can be increased is to create series of cavities in the material. Dendrolight cellular material utilizes this approach and by using profiling and cross lamination processes, the cellular material can be produced up to 46% lighter than solid wood the panel is made from.. At present Dendrolight three layer panels have wide non - structural applications in furniture and door production industries. Initial research of cellular wood material mechanical properties (Iejavs et al., 2009; 2011; 2013) and start-up of the new industrial plant in Latvia with manufacturing capacity of 65 thousand m^3 cellular wood panel material per year lead to the necessity to use cellular wood material in building industry as construction material.

The aim of the research was to evaluate the thermal properties of three layer cellular wood panels for applications in construction. Industrially produced Scots pine (*Pinus sylvestris* L.) cellular wood material was used to create test specimens to determine coefficient of thermal conductivity. There are several structural materials (fiberboard, chipboard, strand board, plywood and solid timber panels) that can be combined with cellular material to produce structural sandwich panels. In this research only Scots pine cellular wood panels with 4 mm thick high -density fiber board faces were tested.

Materials and Methods

Cellular wood material for thermal conductivity test samples was produced using 28 mm thick European pine (*Pinus sylvestris* L.) profiles. The profiles are produced by several planning procedures - first board is planed from all four sides. After planing, 8 double faced grooves were cut into longitudinal direction in the flat faces of board with the following dimensions of the grooves: depth of 24 mm, pitch of 6.4 mm and width of 3.2 mm. The average moisture content of the profiles in production process was 12%. One component polivinylacetate (PVA) adhesive Cascol 3353 was used for all gluing operations in

cellular wood material and panel production. Each layer was aligned horizontally in 90 degree direction to the previous layer. Four layers of grooved boards were used to produce 112 mm thick cellular wood panel.

Two types of test panels were produced - A and B to determine coefficient of thermal conductivity for each direction of cellular wood material. Specimen type A is produced by adding two face layers on top of the cellular wood panel in parallel direction. Specimen type B is produced by cutting cellular wood panel in slices and orienting the layer plane perpendicular to panel plane see Figure 1. The faces of both panels were made of 4 mm thick high - density fiberboard (HDF). Average density of the fiberboard according to the producer was ρ_{HDF}= 800 kg·m^{-3} and thermal conductivity l_{HDF}=0.14 W·m^{-1}K^{-1} according to EN 13986: 2004.

Cellular wood material has two main directions; parallel (sample type A with suffix - $_0$ on property) and perpendicular (sample type B with suffix - $_{90}$ on property). The average value of cellular wood material density was ρ_{CWM}=302 kg·m^{-3} determined by measuring and dividing specimen mass by dimension. Cellular wood material apparent density compared with solid pine timber density at 12% moisture content (Wagenführ, 1996) was 40% less on average. The average moisture content value of test samples was 12.1 % determined after thermal conductivity test. Moisture content was determined by weighing and drying method according to the standard EN 13183-1:2003. The test samples with nominal dimensions of 600×600 x120 mm for both specimen types were used to determine coefficient of thermal conductivity and thermal transmittance. Illustration of the test panels is given in Figure 1.

Coefficient of thermal conductivity and thermal transmittance of test samples was determined according to standard EN 12667:2002. In total four samples were tested, each cellular wood material direction was represented by two sample CWM panels covered with HDF. Tests were performed on hot plate thermal conductivity instrument FOX 600 which met standard ISO 8301:2001 requirements in 2012 in the Tursons ltd. building material testing laboratory.

Thermal conductivity l (W·m^{-1}·K^{-1}), for core layer of a sandwich panel having faces of equal thickness and the same material is calculated using Equation 1 and 2.

$$U_{sample} = \frac{1}{R_0} \rightarrow R_0 = \frac{1}{U_{sample}} \quad (1)$$

where

U_{sample} – tested thermal transmittance of specimen, W·m^{-2}·K^{-1};

R_0 – thermal resistance of test specimen (specimen thermal resistances of warm and cold surfaces are not included), m^2·K·W^{-1}.

$$R_0 = 2 \cdot \frac{d_1}{\lambda_1} + \frac{d_2}{\lambda_2} \rightarrow \lambda_2 = \frac{d_2 \lambda_1}{R_0 \cdot \lambda_1 - 2 \cdot d_1} \quad (2)$$

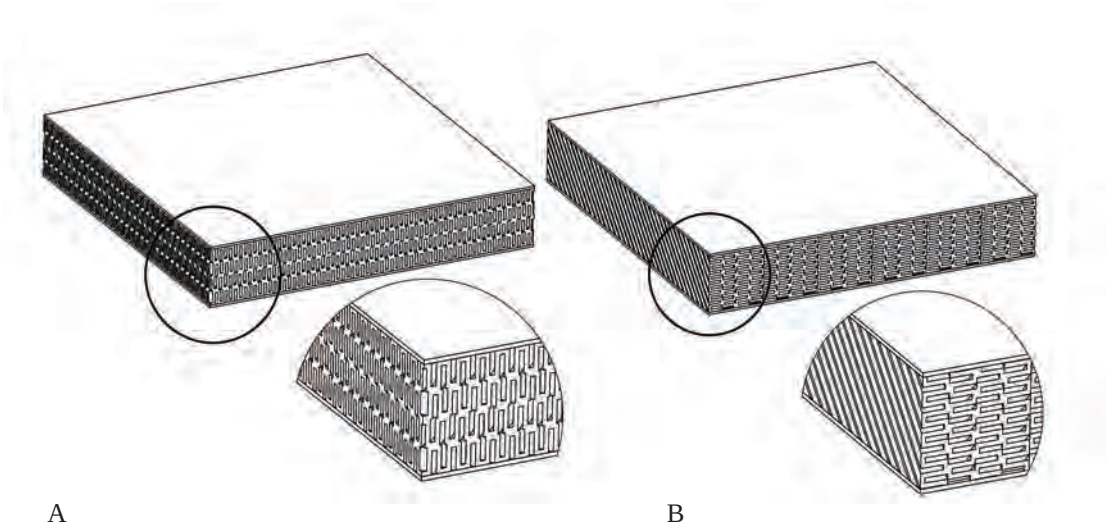
where

d_1 – thickness of surface layers, mm;

d_2 – thickness of cellular wood core, mm;

λ_1 – thermal conductivity of surface layers, W·m^{-1}·K^{-1};

λ_2 – thermal conductivity of cellular wood material core, W·m^{-1}·K^{-1}.



A B

Figure 1. Illustration of the sample types: A-with parallel direction of cellular wood material and B-with perpendicular direction of cellular wood material.

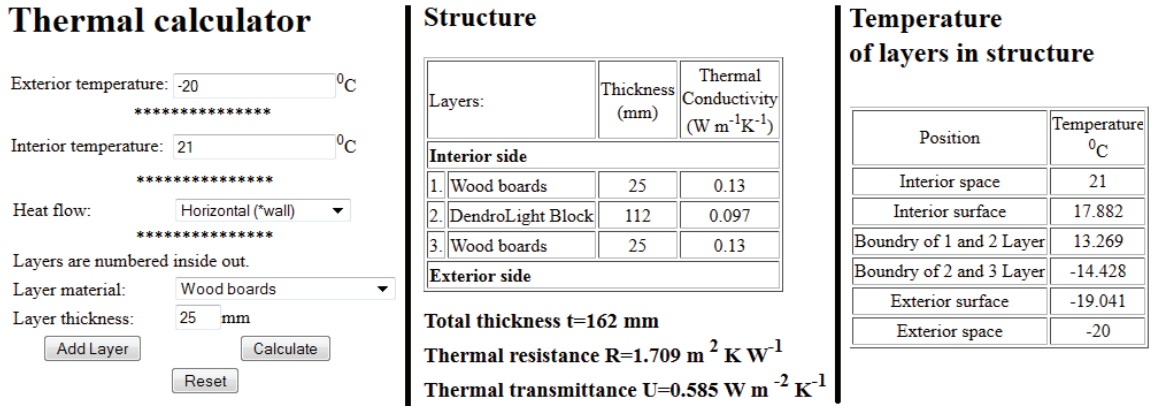


Figure 2. Illustration of the layout of thermal calculation software.

Thermal transmittance coefficient of possible wall constructions was calculated according to EN 6946-2008. Interior and exterior surface resistances for walls are assumed as follows R_{si}=0.13 $m^2 \cdot K \cdot W^{-1}$ R_{se}=0.04 $m^2 \cdot K \cdot W^{-1}$. To precisely determine the thermal transmittance requirements for building envelope according to LBN 002-01, it is necessary to calculate the weight of the structure - in this case a wall. Density of wooden boards used in sandwich panels for construction purposes is assumed to be ρ_{wood}=500 $kg \cdot m^{-3}$ (Wagenführ, 1996) thermal conductivity of European pine wood is l_{wood}=0.13 $W \cdot m^{-1} \cdot K^{-1}$ according to standard EN 12524:2003. Thermal properties of another related building material for calculation purposes were obtained from standard EN ISO 10456:2008. In 2013 within the project "Research of wood material with high ecological value" calculation software was developed to ease the assessment procedure of CWM thermal properties. Illustration of the layout of calculation software can be seen in Figure 2.

Thermal calculator can be used to calculate heat flows in three different directions: horizontal, vertical up, and vertical down. Eight different predefined construction materials and three types of air gaps are available to define layers of structure. When each individual layer is defined by choosing the layer material and layer thickness, the layer should be added by clicking on the add layer button. When all layers are defined to calculate the thermal transmittance and temperature in each boundary layer, the calculate button should be pressed. The calculated results are displayed as illustrated above.

Results and Discussion

Coefficient of thermal conductivity and thermal transmittance of cellular wood material test samples determined according to standard EN 12667:2002 and estimated according to equation 1 and 2 are presented in Table 1. To provide some insight into the result variation, calculated results are provided for each tested sample separately.

Since the coefficient of thermal conductivity of parallel direction of cellular wood material (Type A) compared to perpendicular direction of material (Type B) is significantly (34%) lower, this direction will be used for further structural panel design. The comparison of CWM thermal conductivity to other construction material thermal conductivity is presented in Figure 3. Thermal conductivity of both CWM types compared to clay and concrete building materials are much better, but if CWM is compared

Table 1

Coefficient of thermal conductivity and thermal transmittance of cellular wood material

Specimen type	Thickness t, mm	Thermal conductivity (combined) λ_{10}, $W \cdot m^{-1} \cdot K^{-1}$	Thermal transmittance (combined) U, $W \cdot m^{-2} \cdot K^{-1}$	Thermal conductivity (surfaces) λ_1, $W \cdot m^{-1} \cdot K^{-1}$	Thermal conductivity (core) λ_1, $W \cdot m^{-1} \cdot K^{-1}$	Average thermal conductivity (core) λ_1, $W \cdot m^{-1} \cdot K^{-1}$
A	120.98	0.101	0.8348	0.18	0.098	0.097
A	120.93	0.100	0.8269	0.18	0.097	
B	121.64	0.148	1.2167	0.18	0.146	0.148
B	121.64	0.151	1.2414	0.18	0.149	

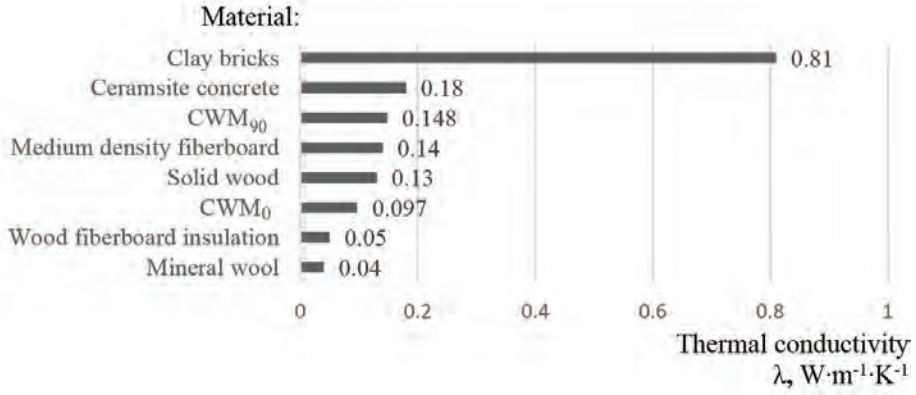


Figure 3. Thermal conductivities of various materials: CWM_{90} – cellular wood material in perpendicular direction and CWM_{90} – cellular wood material in parallel direction. (LBN 002-01).

to solid wood, CWM_0 is 25% better, but CWM_{90} is 13% worse.

In this research two different thermal performance requirements regarding the wall thermal transmittance are analyzed - Latvian Construction standard and passive house standard. Latvian Construction Standard LBN 002-01 states that the thermal transmittance of walls with weight less than 100 $kg \cdot m^{-2}$ should

Table 2

Thermal transmittance of six different wall structures where cellular wood material (CWM) in parallel direction is used

Case	Wall structure	Thickness of layer t, mm	Thermal conductivity $\lambda, W \cdot m^{-1} \cdot K^{-1}$	Wall weight $kg \cdot m^{-2}$	Thermal transmittance $U, W \cdot m^{-2} \cdot K^{-1}$	Comments
1	Wood boards	25	0.13	37	0.93	Thinnest standard panel for construction based on production technology
	CWM_0	56	0.097			
	Wood boards	25	0.13			
2	Wood boards	25	0.13	56	0.59	Thickest standard panel for construction based on production technology
	CWM_0	112	0.097			
	Wood boards	25	0.13			
3	Wood boards	25	0.13	104	0.30	Theoretical panel to meet LBN 002-01 requirements
	CWM_0	270	0.097			
	Wood boards	25	0.13			
4	Wood boards	25	0.13	200	0.15	Theoretical panel to meet passive standard requirements
	CWM_0	590	0.097			
	Wood boards	25	0.13			
5	Wood boards	25	0.13	57	0.23	Optimal building envelope that meets the requirements of LBN 002-01
	CWM_0	56	0.097			
	Wood boards	25	0.13			
	Insulation material	125	0.04			
6	Wood boards	25	0.13	82	0.15	Optimal building envelope that meets the requirements of passive standard
	CWM_0	56	0.097			
	Wood boards	25	0.13			
	Insulation material	225	0.04			

not exceed 0.25 $W \cdot m^{-2} \cdot K^{-1}$ but for walls with weight greater than 100 $kg \cdot m^{-2}$ the thermal transmittance must be lower than 0.30 $W \cdot m^{-2} \cdot K^{-1}$. Passive standard strictly does not specify the criteria for maximal thermal transmittance of wall, it has series of rules for building as a system to comply with. Commonly used thermal transmittance of passive house wall is assumed to be in range of 0.10-0.15 $W \cdot m^{-2} \cdot K^{-1}$ depending on building design – glazed areas, building size etc. and location of building.

Standard panels (Table 2: case No. 1, 2), which can be produced using 28 mm thick profiles, have significantly greater thermal transmittance than stated in LBN 002-01 requirements. The application of such panels without extra thermal insulation material in dwellings and public buildings is not acceptable. In Northern Europe the use of such panels without insulation is possible only in building temporary, seasonal and hobby houses.

The theoretical solution of extremely thick CWM_0 core (Table 2: case No. 2, 3) is irrational from many aspects: material consumption-economics and logistics, structural risks of increased shear deformations in panel and unpredictable behavior of panels. Therefore, the solution when CWM building panels are not insulated should not be used.

In the Table 2: case No. 5, 6, it is assumed that 106 mm thick CWM_0 building panel is sufficient from structural aspects. To meet the thermal requirements of LBN 002-01, maximal thermal transmittance of wall can be 0.25 $W \cdot m^{-2} \cdot K^{-1}$ (weight of wall < 100 $kg \cdot m^{-2}$), but for Passive standard the requirements are even harder to meet - the maximal thermal transmittance of wall should be just 0.15 $W \cdot m^{-2} \cdot K^{-1}$. Based on previous cases, it is clear that insulation material is needed to achieve required thermal performances. To meet the LBN 002-01 requirements, 106 mm thick CWM_0 building panel should be combined with 125 mm thick insulation material, but to meet passive standard requirements, the insulation layer should be increased to 225 mm.

An optimal solution for construction purposes in Northern Europe is to use CWM_0 building panels in combination with insulation material. To effectively estimate the panel that is best for each case, a calculation process should start with an evaluation of structural behavior of panel. When the panel is detailed, the insulation layer thickness should be calculated based on thermal requirements of the building.

Conclusions

1. Thermal conductivity of cellular wood material is highly direction dependent – a thermal conductivity in parallel direction (λ_0=0.0977 $W \cdot m^{-1} \cdot K^{-1}$) is up to 34% better than a thermal conductivity measured in perpendicular direction (λ_{90}=0.148 $W \cdot m^{-1} \cdot K^{-1}$). Therefore, from thermal properties viewpoint for construction purposes parallel orientation of cellular wood material is much more effective.
2. The thermal resistance of CWM is not sufficient to provide acceptable levels of thermal transmittance of the whole structure. Therefore, to achieve requirements of LBN and passive standard, it is strongly recommended to use cellular wood material sandwich panels in combination with insulation material.
3. The calculation software that was developed in research process is an excellent tool for a fast estimation of thermal transmittance and thermal resistance of wall. Application also calculates the temperatures on boundary surfaces of building envelopes. These temperatures can be used to evaluate the surface condensation risks. Further development process of software should be continued. To add the functionality of moisture risk damage assessment, it is necessary to determine the water vapor resistance factor of cellular wood material.

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References

1. LVS EN 12524 (2003) Latvijas Standarts. *Būvmateriāli un būvizstrādājumi - Higrotermiskās īpašības - Projektos lietojamo vērtību tabulas.* (Building materials and products - Hygrothermal properties - Tabulated design values). 17 lpp. (in Latvian).
2. LVS EN 12667 (2002) *Latvijas Standarts. Būvmateriālu un būvizstrādājumu termiskā efektivitāte - Termiskās pretestības noteikšana ar aizsargātās karstās plāksnes un kalorimetra metodi - Izstrādājumi ar zemu un vidēju termisko pretestību.* (Thermal performance of building materials and products - Determination of thermal resistance by means of guarded hot plate and heat flow meter methods - Products of high and medium thermal resistance). 56 lpp. (in Latvian).
3. LVS EN 13183-1 (2003) Latvijas Standarts. *Zāģmateriālu mitrums - 1.daļa: Noteikšana ar žāvēšanas metodi.* (Moisture content of a piece of sawn timber - Part 1: Determination by oven dry method*).* 6 lpp. (in Latvian).

4. LVS EN 13986 (2004) Latvijas Standarts. *Celtniecībā lietojamās koksnes plātnes - Īpašības, atbilstības novērtēšana un marķēšana.* (Wood-based panels for use in construction - Characteristics, evaluation of conformity and marking). 58 lpp. (in Latvian).
5. LVS EN ISO 6946 (2008) Latvijas Standarts. *Ēku būvkomponenti un būvelementi. Siltumpretestība un siltumapmaiņas koeficients. Aprēķināšanas metodika.* (Building components and building elements. Thermal resistance and thermal transmittance. Calculation method). 36 lpp. (in Latvian)
6. LVS EN ISO 10456 (2008) Latvijas Standarts. *Būvmateriāli un būvizstrādājumi. Higrotermiskās īpašības. Projektos lietojamo vērtību tabulas un deklarēto un aprēķina siltumtehnisko vērtību noteikšanas procedūras.* (Building materials and products - Hygrothermal properties -Tabulated design values and procedures for determining declared and design thermal values). 58 lpp. (in Latvian).
7. Iejavs J., Spulle U. (2013) Structural properties of cellular wood material. Available at: http://www.proligno.ro/ro/articles/2013/201304.htm, 16 January 2014.
8. Iejavs J., Spulle U., Domkins A., Buksans E. (2009) Dendrolight tipa vieglās plātnes no apses koksnes (Dendrolight Panels Produced from Aspen Wood). In: Andersons B. (eds) *Lapu koku audzēšanas un racionālas izmantošanas pamatojums, jauni produkti un tehnoloģijas,* Latvian State Institute of Wood Chemistry, Riga, pp. 115 – 119. (in Latvian).
9. Iejavs J., Spulle U., Jakovļevs V. (2011) Evaluation of bending properties of three layer cellular wood panels using six different structural models. In: Research for Rural Development 2011 *Proceedings of the 17th International Scientific Conference*, Vol. 2, May 18-20, LLU, Jelgava, Latvija, pp. 85 – 90.
10. LVS EN ISO 8301(2001) Latvijas Standarts. *Siltuma izolācija - Siltuma pretestība un ar to saistīto īpašību noteikšana stacionārā režīmā - Siltuma plūsmas mērīšanas ierīce*. (Thermal insulation - Determination of steady-state thermal resistance and related properties - Heat flow meter apparatus). 38 lpp. (in Latvian).
11. LBN 002-01 (2001) Thermotechnics of Building Envelopes. Available at: http://www.buildup.eu/fr/publications/31161, 10 March 2013.
12. Pflug J., Vangrimde B., Verpoest I. (2003) Material efficiency and cost effectiveness of sandwich materials. Available at: http://sirius.mtm.kuleuven.be/Research/C2/poly/phds/jp/jp_sampe_us_2.pdf, 15 February 2013.
13. Skuratov N. (2010) New Lightweight solid wood panels for green building. Available at: http://www.swst.org/meetings/AM10/pdfs/IW-4%20skuratov%20paper.pdf, 26 February 2013.
14. Wagenführ R. (1996) *Holzatlas* (Wood Atlas). Vol 4. Fachbuchverl. Leipzig, Germany, 214 S. (in German).
15. Voth C.R. (2009) Lightweight sandwich panels using small-diameter timber wood-strands and recycled newsprint cores. Available at: http://www.dissertations.wsu.edu/Thesis/Fall2009/c_voth_120609.pdf, 08 January 2013.

RELATIONSHIP BETWEEN MECHANICAL AND ELECTRIC CUTTING POWER AT LONGITUDINAL SAWING

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Abstract
When the measurements of power consumed by cutting mechanism electromotor are made, the mechanical cutting power cannot be obtained, because they are different physical processes. However, determination of electricity power is relatively simpler. Therefore, both powers are determined in the study, in order to evaluate coherence between them. Computer numerical control machine was used for climb-sawing of aspen (*Populus tremula* L.) wood with a circular saw. Mechanical cutting power was calculated from measurements of cutting force, but the electric ones – from measurements of current and voltage. As a result, changes of both powers and of specific cutting work, on what the analytical calculation of cutting power is based, were obtained depending on length of the cutting trajectory. It is found out, that mechanical cutting power is greater than electric power, and it is useful to use for the analytical calculation, based on determination of the specific cutting work, wear coefficient of the cutter that depends not only on the duration of work of cutter, but also on feed speed and the length of the cutting trajectory.
Key words: circular saw, sawing, cutting power, cutting force, specific cutting work, aspen.

Introduction

Several methods can be used for determination of cutting power – the direct and analytical ones. Most commonly used methods for direct determination of cutting power are based on measurement of electricity consumed by motor for drive of cutting tool. One of such methods is the determination of changes in the electrical current that has been consumed by an electrical motor (Barcík et al., 2010). The other method though compares the power of the electrical motor before and during the cutting process, resulting in a difference that indicates the power that has been consumed (Ābele and Miončinskis, 2012; Cristóvão et al., 2013). However, only electrical power can be determined by using these two above mentioned methods. Thus, they do not provide direct and accurate results, knowing that the cutting process is characterized best by the mechanical power.

For the direct determination of mechanical cutting power, the most accurate method is measurement of torque of drive spindle (Kováč and Mikleš, 2010; Svatoš et al., 2011), because thus it is possible to determine the resistance created by wood when cutter is deepening in the wood. Cutting power in this case is calculated according to such equation (1) (Kováč and Mikleš, 2010):

$$N_{gr} = \frac{2 \cdot 1000 \cdot M \cdot v}{D}, \quad (1)$$

where N_{gr} is cutting power, W. M is torque of spindle, N m. v is cutting velocity, m s^{-1}. D is diameter of cutting circumference, mm.

However, the use of this method is related to greater investments of financial resources, because costs of torque transducer are greater than, for example, of wattmeter, by what the electric power is determined. Thus, the measurement of electric power is economically more favourable, but, in order to apply this to the mechanical cutting power, it is necessary to determine correlation between them.

For the analytical calculation of cutting power, equation (2) is developed, which is based on the specific cutting work:

$$N_{gr} = \frac{K \cdot b \cdot H \cdot u}{60}, \quad (2)$$

where N_{gr} is cutting power, W. K is specific cutting work, J cm^{-3}. b is kerf width, mm. H is kerf height, mm. u is feed speed, m min^{-1}.

For calculation of equation (2), the specific cutting work is usually determined by the method of correction coefficients (Бершадский, 1967). However, this method is not perfect, because it does not include all factors, but evaluation of the included factors is often inadequate and unobjective. Other authors also point out this (Porankiewicz et al., 2011). One of factors, evaluation of what is restricted, is a wear of cutter, because the determination of it provided only depending on duration of work of cutting tool.

Basis on the above mentioned objective of the study is to determine correlation between the mechanical and electric cutting power, which can be used for direct measurements of power and to improve evaluation of wear coefficient of the cutter, which is provided for analytical calculation of the power.

The tasks are the following:

1. to measure mechanical and electric power and to determine interrelationships between those in the longitudinal sawing;
2. to develop equation for the coefficient of cutting tool wear that evaluates not only duration of work of cutting tool.

Materials and Methods

A multifunctional computer numerical control (CNC) machine with a separate drive mechanism of the circular saw 'Biese Rover 325' was used in this study. Parameters of the CNC machine are given in Table 1.

A unique circular saw has been designed for the experimental work (according to Ābele and Tuherm, 2013). The circular saw was produced by the cutting tool producer from Latvia – 'Nook Ltd.'. Cold-rolled steel 75Cr1 (according to LVS EN 10027-1:2005) was used for body manufacturing of the circular saw. Chemical composition of the 75Cr1 steel is the following: C 0.70 – 0.80%, Mn 0.60 – 0.80%, Cr 0.30 – 0.40%, Si 0.25-0.50%. Tips of the circular saw were made of tungsten cemented carbide K10 (according to ISO) and its chemical composition is the following: WC (tungsten carbide) 94.12%, Co 5.60%, other chemical elements 0.28%. The parameters of the circular saw are indicated in Table 2. This circular saw consists only of two teeth that are located on the opposite circumference points of the circular saw. Therefore, it takes less time to reach the prescribed load capacity for the saw teeth comparing to standard circular saws. This is characterized by an efficient cutting distance per tooth that is 10,000 m related to a single tooth of the circular saw.

Samples of aspen wood with a moisture content of 8 to 10% were used during the experiment work of the study. Climb-sawing was carried out by creating longitudinal kerfs next to each other on both wider sides of the wood sample, leaving 3 mm wide partition between the kerfs (Figure 1). Therefore, an enclosed cutting process was ensured for every kerf, what is a normal characteristic of sawing. Overall, ten kerfs were deposited in one wood sample (five on the one side and five on the other side). Kerfs were performed in depth of 24 mm what gives a 56.1 mm long length of the cutting trajectory for every rotation of the spindle. For the length of the cutting trajectory at one rotation of the spindle calculating the following equation (3) was used:

$$l = \frac{10^3 \cdot u}{n \cdot z} + \frac{\pi \cdot D}{360} \arccos\left(1 - \frac{2 \cdot H}{D}\right), \quad (3)$$

where l is length of the cutting trajectory at one rotation of the spindle, mm. u is feed speed, m min^{-1}. n is rotation frequency of spindle, min^{-1}. z is number of teeth of the circular saw. π is the constant ($\pi = 3.14$) D is diameter of cutting circumference, mm. H is kerf height, mm.

The total length of the cutting trajectory related to the one saw tooth was calculated by the following equation (4):

Table 1

Technical parameters of the computer numerical control machine

Characteristics	Value
Rotation frequency of spindle, min^{-1}	0…18000
Feed speed, m min^{-1}	0…60
Power of electromotor, kW	3.4
Electromotor power factor cos φ	0.85
Maximum processing length of the x-axis direction, mm	3000
Maximum processing length of the y-axis direction, mm	900

Table 2

Parameters of the cutting regime

Characteristics	Value
Diameter of cutting circumference D, mm	120
Body thickness s, mm	2
Kerf width b, mm	3
Clearance angle α, degree	35
Sharpness angle β, degree	40
Rake angle γ, degree	15
Cutting velocity v, m s^{-1}	50
Feed speed u, m min^{-1}	8
Rotation frequency n, min^{-1}	7958
Feed per tooth u_z, mm	0.503
Kerf height H, mm	24

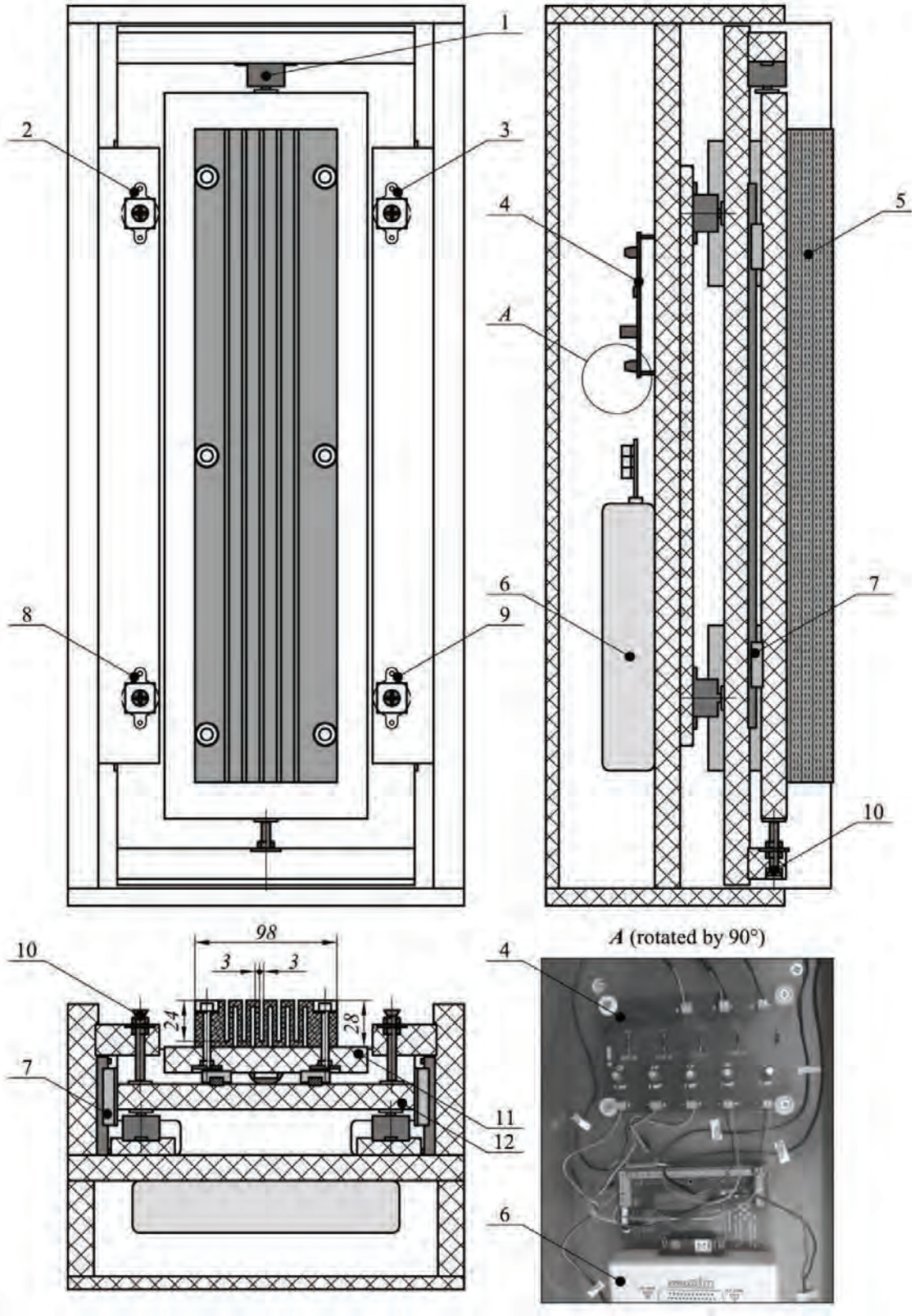

Figure 1. Cutting force measurement device.
1 – horizontally force sensor; 2, 3, 8, 9 – vertically force sensors; 4 – direct current ripple reduction filter; 5 – wood sample; 6 – data logger; 7 – linear guide rails; 10 – adjustment screws; 11 – horizontally movable platform; 12 – vertically movable platform.

$$L = \frac{l \cdot n \cdot l_p}{10^6 \cdot u \cdot z} \cdot m_{ie} \cdot m_p, \quad (4)$$

where L is total length of the cutting trajectory, m. l is length of the cutting trajectory at one rotation of the spindle, mm. n is rotation frequency of spindle, min^{-1}. l_p is length of the wood sample (l_p = *450*), mm. u is feed speed, m min^{-1}. z is number of teeth of the circular saw. m_{ie} is number of kerfs in one wood sample. m_p is number of wood samples.

During the sawing samples of wood were fastened in a device of special construction (Figure 1) provided for determination of the cutting force. The device consists of two platforms; it is possible to move one of them in a horizontal direction, but the other one – in a vertical direction by the use of linear guide rails. Besides, the platform that can be moved horizontally was connected to the platform that can be moved vertically. Therefore, the sample of wood directly fixed on the platform that can be moved horizontally, can move both horizontally and vertically. For the measurement of force, there are mounted sensors of force 'Measurement Specialities™' FC22 (measuring range: 0 to 100 lbf) in the device; working of them is based on changes of voltage of supplied power depending on the force with what pressure is applied on the sensible surface. One of the sensors is located at the end of the platform that can be moved horizontally, but four force sensors are placed under the platform that can be moved vertically. There are adjustment screws located opposite to each sensor, with what platforms are pressed to the sensors. Thus, it is ensured that during cutting platforms are in continuous contact with the sensors and cannot move freely away from them, but at the same time a possibility of moving is given to them in the direction to the sensors, so that they could apply pressure to the sensible surfaces of sensors. Each sensor was connected to data logger PicoLog ADC-20 through terminal board by the use of single ended channels. Considering that only four sensors can be connected to the data logger, but it is necessary to carry out measurements with five sensors, vertically located sensors were connected in pairs (2 with 3 and 8 with 9; Figure 1), i.e., (+) terminal of one of sensors connected in a pair and (-) terminal of the other sensor connected in the same pair was connected to the data logger, but (-) terminal of the first sensor was connected to (+) terminal of the other sensor. Thus, one result of measurement is obtained from sensors connected in a pair. Three 5 V stabilized power supply modules are used for supply of sensors with input voltage – for one of sensors connected in each pair a separate power supply module is used, but for other sensors one common power supply module is used. Besides, the direct current ripple reduction filter is included in the electric circuit of each power supply of sensor. It consists of the resistor (270 Ω) connected in series circuit and capacitor (1000 μF) connected in parallel.

Direction of the cutting force vector for circular saws depends on its turning angle and therefore is not constant. Therefore, with the device of measurement of force, it is possible to state only vertical and horizontal components of the cutting force. The horizontally placed sensor registers the horizontal component of cutting force, but four vertically placed sensors – the vertical component of cutting force. The total value of the vertical component is obtained by summing of two results of measurements obtained from both pairs of vertical sensors. When sawing of wood sample is started, the cutter of circular saw applies greater pressure on the pair of vertical sensors placed closer to them. When the circular saw gradually moves further, it is applying more and more pressure on the other pair of vertical sensors, but pressure applied to the first pair diminishes, and at the end of cutting, the greatest force of pressure is already applied on the other pair of sensors. This means that the total component of vertical force is divided on both pairs of sensors.

Data logger transmitted the data registered by force sensors to computer, in what by use of software PicoLog Recorder results of performed measurements were stored in both characteristic curves and numeric data (spreadsheet). From obtained data the value of the resulting vector of the cutting force (5) and value of the mechanical cutting power (6) were calculated by the use of such equations:

$$P_{gr} = k \cdot \sqrt{P_{//}^2 + \left(P_{\perp 1} + P_{\perp 2}\right)^2}, \quad (5)$$

$$N_{gr}^m = P_{gr} \cdot v, \quad (6)$$

where P_{gr} is cutting force, N. k is conversion factor from lbf to N $(k = 4.448222)$. $P_{//}$ is horizontally component of cutting force, lbf. $P_{\perp 1}$ and $P_{\perp 2}$ are vertically components of cutting force, lbf. N_{gr}^m is mechanical cutting power, W. v is cutting velocity, m s^{-1}.

For the determination of consumed electric power of electromotor of cutting mechanism, measurements of voltage and current were used. Measurements of phase voltage were performed with analogue voltmeter ABB VLM1 (measuring range: 0 to 500 V, point value 20 V) only between one of phases and neutral, because star connection of the electromotor has a symmetric load. This means that voltage is equal between each of phase wires and neutral wire. For the measurement of current, sensors of electromagnetic loops were put around each of three line wires. Current was measured in line wires, because in star connection a line current is equal to the phase current. All three current sensors

were connected with the data logger PicoLog CM3 that transmitted the registered data to computer, where they were processed by software PicoLog Recorder. Only differences of current between the consumed current during the cutting process and the consumed current during the idle running were used in calculations. The active electric cutting power was calculated by such equation (7):

$$N_{gr}^{el} = U_F \cdot (I_{L1} + I_{L2} + I_{L3}) \cdot \cos\varphi, \quad (7)$$

where N_{gr}^{el} is electric power, W. U_F is phase voltage, V. I_{L1}, I_{L2} and I_{L3} are line amperages, A. φ is phase difference angle between voltage and current degree.

Specific cutting work was calculated by the following equation (8) (Marthy and Cismaru, 2009):

$$K = \frac{N_{gr}^{m} \cdot 60}{b \cdot H \cdot u}, \quad (8)$$

where K is specific cutting work, J cm^{-3}. N_{gr}^{m} is mechanical cutting power, W. b is kerf width, mm. H is kerf height, mm. u is feed speed, m min^{-1}.

Regression was used for interaction's analysis between cutting power and length of the cutting trajectory because it is the most suitable for cutting process models (Naylor et al., 2012). According to F-test with a p-value (with software IBM SPSS Statistics 19) hypotheses about the significance of the regression equations were tested $(H_0 : \rho^2 = 0, H_1 : \rho^2 > 0)$; but with p-value of t-test hypotheses about the significance of the regression coefficients $H_0 : \beta_1 = \beta_1^0$ were tested. P-value was compared with significance level $\alpha = 0.01$.

Results and Discussion

The diagram of changes of cutting power (Figure 2) indicates that cutting power evenly increases in the entire length of the cutting trajectory. This can be observed both for the mechanical and electric cutting power. In addition, both trend lines have very similar intensity of increase and essential dependence on length of the cutting trajectory ($p < 0.01$) what means that with one of them the other one can be explained. The most important difference that emerges between the mechanical and electric cutting power is their actual value. At the beginning of experiment, the mechanical cutting power is 1.11 times greater than the electric cutting power, but at the end of the experiment, this proportion is 1.34. These differences confirm the fact that by the measurement of the electric power, the true cutting power cannot be obtained.. It is possible to get the true cutting power only from measurements of the mechanical power, because they result directly from the cutting force. The power of electric energy consumed by the motor is only an indirect describer, but it can be simply determined. Therefore, in processes of longitudinal climb-sawing of aspen wood, in order to determine mechanical cutting power, if the electric power is known and if cutting regime corresponds to the regime used in the study, such equation (9) can be used:

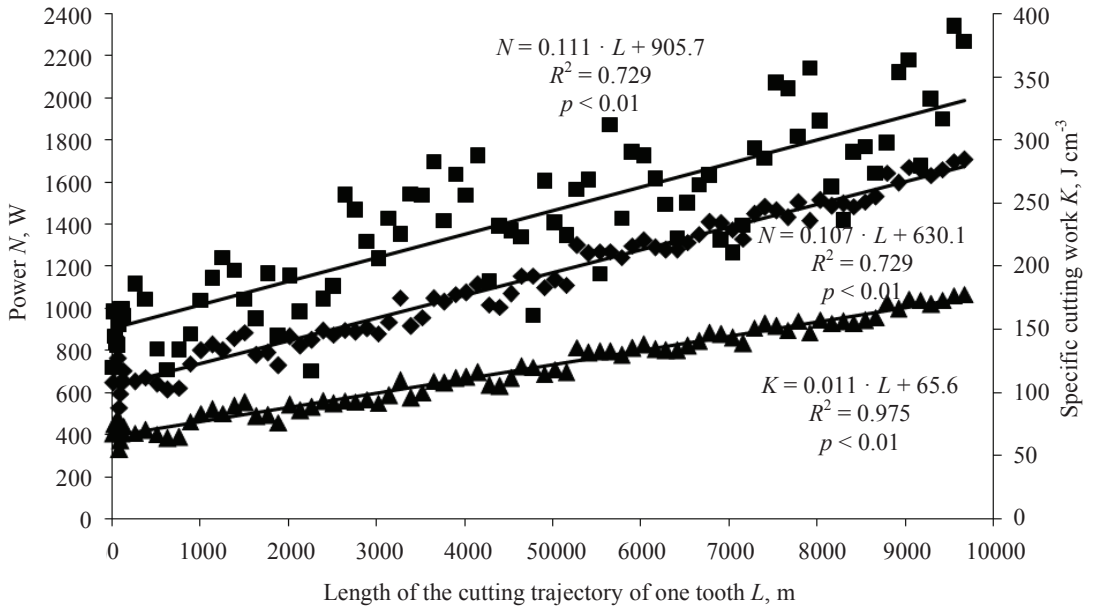

Figure 2. Cutting power and specific cutting work relative to length of the cutting trajectory.
◆ – mechanical cutting power; ■ – electric power; ▲– specific cutting work.

$$N_{gr}^{m} = \frac{N_{gr}^{el} \cdot (0.107 \cdot L + 630.1)}{0.111 \cdot L + 905.7}, \quad (9)$$

where N_{gr}^{m} is mechanical cutting power, W. N_{gr}^{el} is electric power, W. L is length of the cutting trajectory, m.

Unfortunately, changes of the cutting power do not allow distinguishing separate wear periods, because they have a linear character. Also in researches made by other authors, it is found out that the increase of the cutting force (influencing directly the cutting power) is linear (Axelsson et al., 1993). However, Bier and Hanicke, 1963 point out that changes of the cutting force are just the same as changes of rounding of cutting edge, and also those can be divided in three periods. The linear character of changes in this research could be explained by uneven density of wood samples to be processed that changed within the range from 400 up to 550 kg m^{-3}. However, also changes of index obtained by dividing values of cutting power with density of the corresponding wood sample indicate the same linear relationship.

When values of cutting power obtained as a result of measurement (Figure 2) are compared with the calculated ones (using equation 2), it is possible to ascertain that the measured power is greater than the calculated values. Similar tendencies are also observed in researches made by other authors (Aguilera and Martin, 2001). This indicates imperfections in calculation formulas, because equation for determination of the specific cutting work not only disregards mechanical properties and density of wood (as mentioned Porankiewicz et al., 2011), but also wear of cutter and cutting direction relative to feed direction, because studies have shown that climb-sawing require greater cutting power compared to counter-sawing (Cristóvão et al., 2013). The wear of cutter is characterized there with coefficient a_ρ depending on duration of work of cutter. However, duration of work of the cutter is a very relative index, because it depends on feed speed. Although the impact of feed speed on cutting power is less significant (Barcík et al., 2008) compared to cutting speed (although Naylor et al., 2013 points out that also cutting speed does not have an essential impact on cutting force, several other studies point out that it is a significant factor); nevertheless, it essentially affects the determination of the coefficient a_ρ by which the wear of cutter is evaluated. It can be explained by the fact that within the same time with a different feed speed, different length of the cutting trajectory can be achieved; therefore, a different wear of cutter will be caused, too. The value of the specific cutting work under particular circumstances of cutting regime is constant (Bučar and Bučar, 2002). Therefore, the increase of it depending on the length of the cutting trajectory (Figure 2) is caused by the impact of the wear of cutter. This means that in regression equation, $0.011 \cdot L$ is equivalent to the increase of coefficient a_ρ. Thus, for the improvement of accuracy of calculation of the specific cutting work, within the framework of the given cutting regime parameters, following equation (10) can be used, where the length of the cutting trajectory is replaced by an equal relationship formed by simpler determinable parameters of cutting regime – rotation frequency of cutting tool, length of the cutting trajectory at one rotation of the spindle and duration of work of cutter:

$$a_\rho = 1 + \frac{0.011 \cdot n \cdot l \cdot T}{65.6 \cdot 10^3 \cdot z}, \quad (10)$$

where a_ρ is a coefficient that evaluates the cutting tool wear. n is rotation frequency of spindle, min^{-1}. l is the length of the cutting trajectory at one rotation of the spindle, mm. T is duration of cutting tool work after sharpening, min. z is number of teeth of the circular saw.

The cutting power and coefficient, by which the wear of cutter is evaluated, are determined, while cutting regime parameters are constant. Therefore, in further researches, it is necessary to find out the impact of the other cutting regime parameters on them and also other coefficients for calculation of the specific cutting work that have been given in literature (Бершадский, 1967).

Conclusions

1. Mechanical cutting power obtained from measurements of cutting force is not equal to electric power obtained from measurements of current and voltage. Mechanical cutting power, when aspen wood is sawed, is 1.11 to 1.34 times greater than electric cutting power.
2. Specific cutting work changes that cause the wear of cutter, have essential dependence on length of the cutting trajectory ($p < 0.01$, $R^2 = 0.729$). Therefore, the coefficient for calculation of the specific cutting work, by which the wear of cutter is evaluated, can be determined by the developed formula (10) that includes not only duration of work of cutter after sharpening, but also other cutting regime parameters.

References

1. Aguilera A., Martin P. (2001) Machining qualification of solid wood of *Fagus silvatica* L. and *Picea excelsa* L.: cutting forces, power requirements and surface roughness. *Holz als Roh- und Werkstoff*, 59(6), pp. 483 – 488.
2. Axelsson B.O.M., Lundberg Å.S., Grönlund J.A. (1993) Studies of the main cutting force at and near a cutting edge. *Holz als Roh-und Werkstoff*, 51(2), pp. 43 – 48.
3. Ābele A., Miončinskis U. (2012) Parameter changes which characterize the wear of the cutting tool in the milling process of aspen wood. *Pro Ligno*, 8(3), pp. 74 – 88.
4. Ābele A., Tuherm H. (2013) Research methodology of cutting processes of aspen wood. In: Gaile Z., Zvirbule-Bērziņa A., Arhipova I., Assouline G., Ciprovičа I., Bāliņa S., Kaķītis A., Dumbrauskas A., Jansons Ā. (eds) Research for Rural Development 2013. *Annual 19th International Scientific Conference Proceedings*, Volume 2, Latvia University of Agriculture, Jelgava, Latvia, pp. 88 – 94.
5. Barcík Š., Kminiak R., Řehák T., Kvietková M. (2010) The influence of selected factors on energy requirements for plain milling of beech wood. *Journal of Forest Science*, 56(5), pp. 243 – 250.
6. Barcík Š., Pivolusková E., Kminiak R. (2008) Effect of technological parameters and wood properties on cutting power in plane milling of juvenile poplar wood. *Drvna industrija*, 59(3), pp. 107 – 112.
7. Bier H., Hanicke P. (1963) Die spezifische Schnittkraft als Funktion der Schneidenabstumpfung beim Fräsen (The specific cutting force as a function of blunt cutting during milling). *Holztechnologie* 4(2), S. 158-162. (in German).
8. Bučar B., Bučar D.G. (2002) The influence of the specific cutting force and cross-sectional geometry of a chip on the cutting force in the process of circular rip-sawing. *Holz als Roh- und Werkstoff*, 60(2), pp. 146 – 151.
9. Cristóvão L., Ekevad M., Grönlund A. (2013) Industrial Sawing of *Pinus sylvestris* L.: Power Consumption. *BioResources*, 8(4), pp. 6044 – 6053.
10. Kováč J., Mikleš M. (2010) Research on individual parameters for cutting power of woodcutting process by circular saws. *Journal of Forest Science*, 56(6), pp. 271 – 277.
11. LVS EN 10027-1:2005 *Designation systems for steels - Part 1: Steel names*, 25 p.
12. Marthy M., Cismaru I. (2009) Experimental study concerning the power consumption at the milling of pear wood. *ProLigno*, 5(3), pp. 47 – 52.
13. Naylor A., Hackney P., Perera N., Clahr E. (2012) A Predictive Model for the Cutting Force in Wood Machining Developed Using Mechanical Properties. *BioResources*, 7(3), pp. 2883 – 2894.
14. Naylor A., Hackney P. (2013) A Review of Wood Machining Literature with a Special Focus on Sawing. *BioResources*, 8(2), pp. 3122 – 3135.
15. Porankiewicz B., Axelsson B., Grönlund A., Marklund B. (2011) Main and normal cutting forces by machining wood of *Pinus sylvestris*. *BioResources*, 6(4), pp. 3687 – 3713.
16. Svatoš M., Kopecký Z., Rousek M. (2011) Effects of the technology of machining on the surface quality of selected wood. *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis*, 59(6), pp. 329 – 336.
17. Бершадский А.Л. (1967) *Расчет режимов резания древесины* (*Calculation of wood cutting regimes*). Издательство Лесная Промышленность, Москва, 176 с. (in Russian).

REMOVAL OF HEAVY METALS FROM CONTAMINATED SOILS BY ELEKTROKINETIC REMEDIATION

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Abstract
Heavy metals as well as other pollutants are widespread and create deleterious impact to the environment and human health. There are different *in situ* and *ex situ* technologies of immobilization and removal of contaminants; electrokinetic remediation is one of such technologies. It can be applied for treatment of wide areas, e.g., former industrial and military firing-grounds. Technology is applicable to water soluble contaminants at sites with homogeneous soils that are fine-grained and exhibit both, high permeability and high moisture contents. The aim of the study was to test the efficiency of electrokinetic remediation for copper contaminated clayey soil in laboratory conditions. Pilot scale experiments were applied to test the efficiency of electrokinetic removal of contaminants from soil by application of low voltage direct current (DC). Experimental results show that the use of DC power can be selected for treatment of heavy metal contaminated soils. Batch scale experiments were done by using clayey soil with known physical-mechanical properties, spiked with copper solution of known concentrations. Electric force was changed by varying its parameters. The article gives batch experimental results for diffusion of copper ions in soil under the influence of the external electric field.
Key words: copper, electro-osmosis, direct current, electrokinetic remediation.

Introduction

Contamination of soils and groundwater is the modern society's inheritance. All over the world contaminated sites are among the environmental problems of concern. Brownfields, dump sites, former and active industrial and military areas often demand technical and economic evaluation of environmental situation and means to solve the problems of contamination (Shammas, 2009). The 1960's came with ideas about changes in environmental thinking – development that has to be based on environment and industry coexistence (Carson, 1965). Contamination with heavy metals was assessed as important problem as bioaccumulation effects of these pollutants induce direct and indirect hazards to environment and human health (Reddy et al., 1999). Quality of soil and groundwater is fundamentally important, and different technologies are used for the remediation of diffuse and point sources generated by industrial as well as natural contamination. Heavy metals are toxic and hazardous for human health and environment; sources can be of natural origin such as volcanoes and erosion of rocks or anthropogenic such as industry, mining, diffuse air pollution precipitation etc. (Lado et al., 2008).

Electrokinetic remediation is based on the application of direct current electric potential to the contaminated soil by one or more series of electrodes adjusted as anodes and cathodes. The difference of electric potential among anodes and cathodes promotes reactions and transport of non-ionic as well ion species in soil thus resulting in mobilization and transport of contaminants towards electrodes. The main electrokinetic mechanisms are called electro-migration and electro-osmosis. The first creates movement of ionic species towards the electrode of opposite charge in the electric field, hence the electro-osmosis is the motion of liquid induced by an applied potential across a porous material, capillary tube, membrane, microchannel, or any other fluid conduit. The combining effects of the electric field and the electric charge result in electro-osmotic flow towards the cathode (Cameselle and Reddy, 2012). During electrolysis of water at the electrodes ionic products (H^+ and OH^-) are generated and then transported towards these electrodes. Acidic front (H^+) is transported from the anode towards the cathode, but an alkaline (OH^-) - from the cathode towards the anode (Acar and Alshawabkeh, 1993). This causes a pH changes inside the treated matrix: low pH close to the anode and high pH in opposite. Some reports suggest that the pH in soil has significant influence in the contaminant retention and electro-osmotic flow (Gomez et al., 2009; Ko et al., 2000).

Electrokinetic remediation works as it is dramatically changing properties of the soil such as pH, conductivity and temperature; it induces electrolysis of water, sorption processes, promotes acid base reactions and creates ionic flow together with the water. This type of remediation initially was used for heavy metal extraction from contaminated soils, but organic contamination can also be destroyed with the help of electrokinetics (ITRC, 1997).

Electrokinetic remediation technology is potentially effective in both, saturated and unsaturated zones; and it is applicable in soils of low hydraulic conductivity, particularly with high clay content and can treat both organic and inorganic contaminants.

Applicability limitations of electrokinetic technology include low target and high non-target ion concentration and large quantities of iron or iron oxides (U.S. EPA, 2007). Fluid flow occurs due to applied electric field; appropriate placement of electrodes would direct the fluid flow in a controlled manner (Hicks and Tondorf, 1994). Applied electric field creates three interfering processes: electro-osmosis, electro-migration and electrophoresis promoting movement of heavy metal ions in soil, mine tailings or elsewhere (Cameselle and Reddy, 2012).

The aim of the study was to test the efficiency of electrokinetic remediation for copper contaminated clayey soil in laboratory conditions. The tasks of the study were as follows: 1) to spike clayey soil with copper and determine experimental parameters; 2) to perform electrokinetic remediation experiment in batch conditions; 3) to fulfil measurements of electric field and perform analytical studies of soil samples; 4) to model the electrokinetic treatment progress in laboratory scale.

Materials and Methods

Experiments were done using 5 kg of clayey soil with known physical-mechanical properties such as texture and consistency. Soil samples were spiked with known concentration of copper (II) sulphate pentahydrate in order to gain the concentration 350 mg kg^{-1} of copper in soil. Dried soil was sieved through 2 mm sieve, but fractions finer than 0.05 mm were determined by pipette analysis described by Van Reeuwijk, 1995. According to the USDA soil texture classes, fraction of 0.063-2.0 mm is classified as sand, 0.002-0.063 mm – as silt, but finer than 0.063 mm – as clay (FSCC, 2006). Soil pH_{KCl} was measured with a glass electrode in 1 M KCl (1:2.5 mass-to-volume ratio) in triplicates. Cation exchange capacity was determined by methylene blue method (Sarceviča and Actiņš, 2009) and calculated 0.06 mmol g^{-1} (R^2=0.998) Soil pH_{KCl} was measured with a glass electrode in 1 M KCl (1:2.5 mass-to-volume ratio) in triplicates. Clay was put in a plastic box 30 × 20 × 20 cm with perforated sides with 18 holes on each side, longitudinal end plane was used. Diameter of holes was 2.6 mm; the distance between holes was kept 3.5 × 1 cm. Holes were covered with 2 layers of filter paper in order to avoid the electro-osmotic flow of the soil from the box to the outer one – the frame box, which was divided in two sides – water supply side (anodic side) and water discharge side (cathodic side) (Fig. 1.).

Graphite electrodes (100 × 70 × 30 mm) were used, connected with non-copper wire to power supply in chain with controlled DC supply and measuring devices for voltage and electrical intensity. Potential difference was kept stable 41 V (2 V cm^{-1}). The initial checking was done in order to define the polarity of electrodes and to check the DC. Reading between the anode and cathode was the same as applied: 41 V, next point was taken 2 cm away from the anode and another point 2 cm from cathode, the voltage measured by the voltammeter showed 32 V, checking was continued, the reading was decreasing, when the distance between anode and cathode measurements was diminished 40V-32V-24V-16V.

During the first (duration 3 days) and second (40 days) experiment, soil water content was maintained at 65-75% of field soil moisture. It was measured by drying in an oven and calculated. The soil was sampled periodically after application of DC fields (after 1h, 2h, 4h, 8h, 24h, 48h, 72h) during the first cycle of 3 day long experiment and after 10, 20, 30 and 40 days in the second cycle. The electrical currents were recorded constantly after the electrical field was applied. During the experiment soil samples were collected in sections that represent different

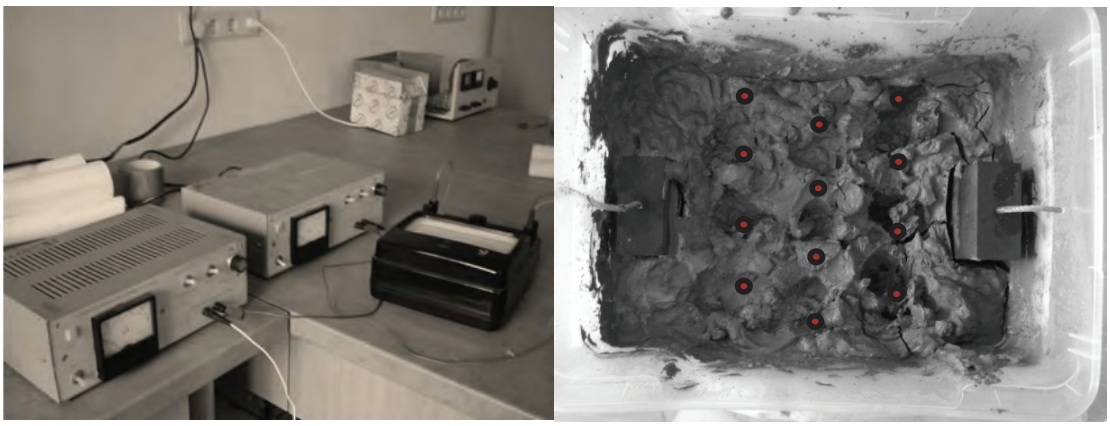

Figure 1. Installation for pilot batch electrokinetic experiments: DC power intensity regulators and voltmeter (left); Graphite electrodes in plastic box with wires connected to power supply (right).

spatial zones among anode and cathode (12 samples after each period). The depth sampled was 5 – 10 cm. The samples were kept in a refrigerator at 4 °C for further analysis. Water was collected nearby the anodic part and analyzed with AAS after the 40 days of experiment.

Preparation of soil for analytical procedures was done by wet digestion with the nitric acid (65% analytical grade, Merck) and measurements by atomic absorption spectrometry (AAS) (PerkinElmer AAnalyst 200) for liquid samples performed with flame atomization and background correction with applied wavelength 324.8 nm.

X-ray powder diffraction (PXRD) analysis for elements and compounds precipitated on electrodes were performed on a Bruker D8 Advance diffractometer (generator 40 kV, 40 mA) with 0.6 mm divergence slits, 0.2 mm detector slit, CuKα radiation (0.15418 nm), 20 interval from 3-60°, scanspeed 0.5 s/step, step 0.02°; therefore X-Ray spectrometer S8 Tiger was used for determination of oxides.

Results and Discussion

Low voltage DC (170 mA at the beginning of the experiments and 68 mA at the end) was applied to test the efficiency of electrokinetic removal of contaminants from soil. During the experiment intensity was falling as the resistance was growing from initial ~1000 W to > 2000 W at the end after 3 days of DC application.

Electrokinetic treatment is effective in both the saturated and unsaturated zone and applicable in clayey soils, thus the experimental design in a box was constructed for clayey soils just under the saturation consistency. Applicability limitations of electrokinetic technology is low concentration of target ions (ITRC, 1997), therefore the contaminated clayey soil was treated in the pilot experiment by promoting three interfering processes: electro-osmosis, electro-migration and electrophoresis. Water flow with target ions in applied electric field was observed, appropriate placement of electrodes allowed controlled experiment in 3 days of the first experimental cycle and 40 days in the second.

Electrokinetic removal of contaminants from soil by application of low voltage DC was observed from some regions of contaminated soil and re-concentrated in other – close to cathode. Experimental results show that the use of DC power can be the solution for treatment of heavy metal contaminated soils, but the treatment should be applied in longer periods. Fig. 2 shows the curve of change of target ion concentrations in three areas – near anode, cathode and in the middle between. The drop in soil pH was mostly limited to half unit to about 4.5-4.7 from 5.0-5.2 initial and it can be due to large quantities of H^+ ions released from anode during the electrokinetic treatment reactions. The difference was observed also between anode and cathode soil distribution areas. Basic front was observed near the cathode (5.5-6.6), but lower (acidic) values closer to the anode (around 4.7) after 3 days of the experiment. After the 40 days, the pH varied in interval of 5.5-6.1 near cathode and 4.0-5.0 near anode.

The concentration of copper in water collected in the pockets (nearby the anode and cathode) after

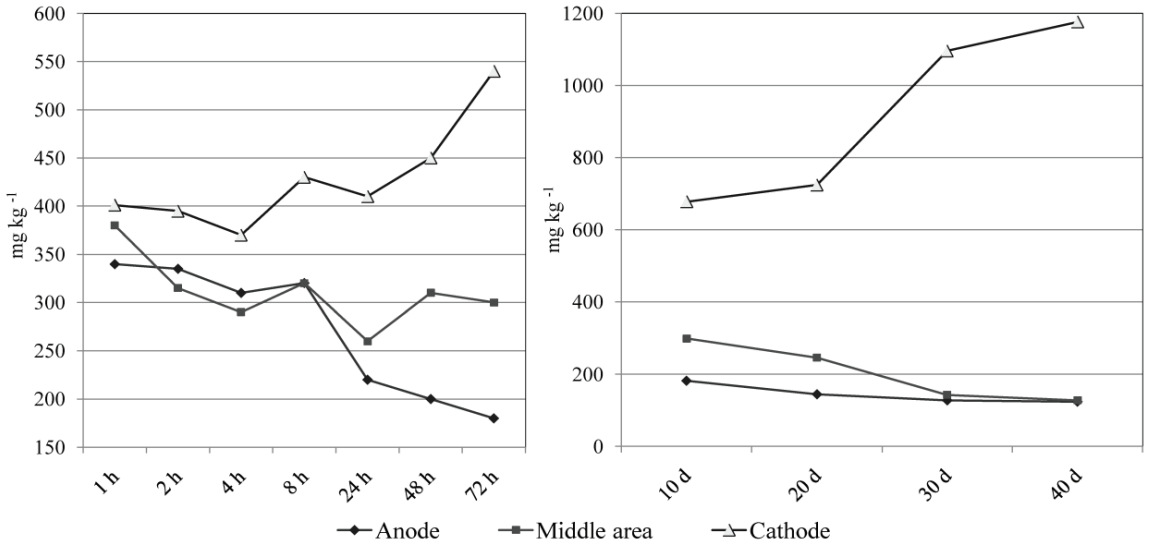

Figure 2. Change of copper concentration in soil in time after application of DC (each curve point (n=4) is calculated average in distinct areas near anode, cathode and in between them). Time period is shown on horizontal scale.

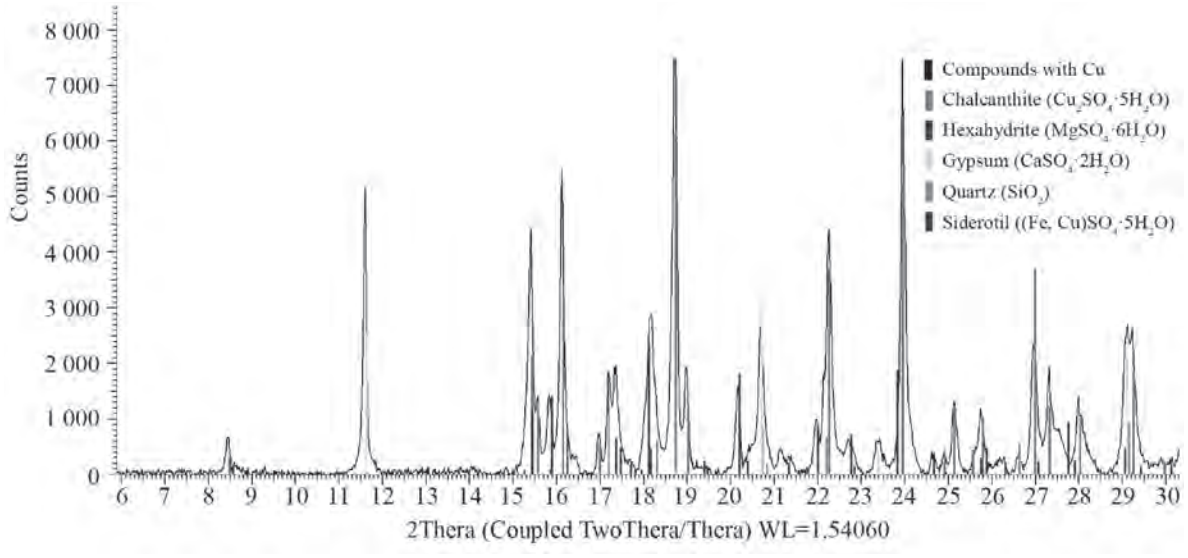

Figure 3. Precipitation of minerals in clay nearby the cathode (distance interval 3 cm from the electrode). PXRD analysis results (XRF results for recalculated oxide units content: SO_3 – 34.3%, CuO – 26.4%, MgO – 6.2%, CaO – 3.4%, ZnO – 1.5%, SiO_2 – 1.3%, Cl – 1.1%).

electrokinetic remediation of 40 days was 0.05 and 0.085 mg L^{-1}, representing a negligible amount (around 0.02 – 0.03%) of the initial metal amount. This means that electro-osmosis was effective in draining the soils from water but unsuccessful in removing the heavy metals out of the soil.

Experimental results proved that target ions under application of DC are moving towards the cathode. In the anodic side the concentration of Cu in soil is diminishing (Fig. 3). No significant changes are observed in the middle of sample containment box during the 3 days of experiment, but after 40 days diminish and are close to results near the anode. Contamination is still left after 40 days of the experiment, but similar concentrations near the anode and in the middle of the box can be explained with the fact that maximal efficiency of ion removal is reached as other part of the contamination is strongly bound with clayey and silt particles. This could be examined in the following experiments by analyzing speciation of copper in the electrokinetically treated clayey soil.

General trends are showing patterns of movement of ions by electromigration; the experiments proved that the electrokinetic treatment of soil can significantly diminish the copper concentration in the contaminated soil.

Conclusions

Experimental results proved that target ions under application of DC are moving towards the cathode. In the anodic side the concentration of Cu in soil is diminishing. The voltage is dependent on moisture content and performance efficiency is highest when consistency of treated soil is close to liquid limit, however, do not exceed it. XRD analysis has shown that the cathodic area is successfully collecting cations – the electrokinetic effect is proven. Basic front was observed near the cathode, but lower (acidic) values closer to the anode, however, not harmful for potential soil animals if applied on a field scale. Contamination is significantly diminished after 40 days of the experiment, but the concentration level near anode and in the middle of the box can be explained with the fact that maximal efficiency of ion removal is reached as the other part of copper ions are strongly bound with clayey and silt particles.

Electrokinesis can be used for remediation and it is applicable to metal extraction at sites with homogeneous soils that are fine-grained and exhibit both enough high permeability and high moisture contents. Pilot testing results have shown that copper ions are removed slowly by electro-osmotic forces, but electromigration effects are undisputable. This experimental study is the first of such kind research in Latvia and it will be continued to improve methodology towards the field scale research.

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References:

1. Acar Y.B., Alshawabkeh A.N. (1993) Principles of electrokinetic remediation. *Environmental Science & Technology*, 27, pp. 2638 – 2647.
2. Cameselle C., Reddy K.R. (2012) Development and enhancement of electro-osmotic flow for the removal of contaminants from soils. *Electrochim. Acta*, 86, pp. 10 – 22.
3. Carson R.L. (1965) *Silent spring*. Penguin UK, London, UK, 336 p.
4. FSCC (Forest Soil Co-Ordinating Centre) (2006) Manual IIIa: Sampling and Analysis of Soil. In: *ICP Forests: Manual on methods and criteria for harmonized sampling, assessment, monitoring and analysis of the effects of air pollution on forests*. UNECE ICP Forests Programme Co-ordinating Centre, Hamburg. p 26, with annexes; Available at: http://icp-forests.net/page/icp-forests-manual, 07 February 2014.
5. Gomez J., Alcantara M.T., Pazos M., Sanroman M.A. (2009) A two-stage process using electrokinetic remediation and electrochemical degradation for treating benzo[a]pyrene spiked kaolin. *Chemosphere*, 74(11), pp. 1516 – 1521.
6. Hicks R.E., Tondorf S. (1994) Electrorestoration of metal contaminated soils., *Environmental Science & Technology*, 28(12), pp. 2203 – 2210.
7. ITRC (1997) Emerging Tehnologies for the Remediation of Metals in Soil. Electrokinetics. Final Report. Interstate Technology and Regulatory Cooperation. Available at: http://www.itrcweb.org/Guidance/GetDocument?documentID=53, 13 February 2014.
8. Ko S.O., Schlautman M.A., Carraway E.R. (2000) Cyclodextrin-enhanced electrokinetic removal of phenanthrene from a model clay soil. *Environmental Science & Technology*, 34, pp. 1535 – 1541.
9. Lado L.R., Hengl T., Reuter H.I. (2008) Heavy metals in European soils: a geostatistical analysis of the FOREGS Geochemical database. *Geoderma*, 148, pp. 189 – 199.
10. Reeuwijk van L.P. (1995) *Procedures for Soil Analysis*. 5th edition, Wageningen, 120. p.
11. Reddy K., Adams J., Richardson C. (1999) Potential technologies for remediation of brownfields. *Practice Periodical of Hazardous, Toxic, and Radioactive Waste Management*, 3(2), pp. 61 – 68.
12. Sarceviča I., Actiņš A. (2009) Sorption analyses of smectite clay. *Latvian Journal of Chemistry*, 3, pp. 187 – 196.
13. Shammas N.K. (2009) Management and removal of heavy metals from contaminated soil. In: Wang L.K., Chen J.P., Hung Y.T. and Shammas N.K. (eds) *Heavy Metals in theEnvironment*, CRC Press, Boka Raton, USA, pp. 381 – 431.
14. U.S. EPA (2007) Treatment Technologies for Site Cleanup: Annual Status Report (Twelfth Edition). Office of Solid Waste and Emergency Response, EPA-542-R-07-012. Available at: http://epa.gov/tio/download/remed/asr/12/asr12_full_document.pdf, 10 February 2014.

EVALUATION OF CUMULATIVE AIR POLLUTION IN RIGA AND LIEPAJA WITH CUMULATIVE POLLUTION INDEX METHOD

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Abstract
Cumulative air pollution – synergy between different pollutants and environmental factors is one of the hardest to evaluate factors in the air quality monitoring field. The evaluation of cumulative effects is hindered by a lack of verified analytical frameworks. Currently used methods are relatively simple and use statistical models with small fixed number of pollutants in association with different factors. There is almost no one solution for direct, on-site cumulative effect measurements. The alternative is the use of Cumulative Pollution Index (CPI) method – solution designed for cumulative effect calculation from bioindication and air quality measurement data. However, this method is completely new and has never been used in the air pollution evaluation activities. Therefore, the objective of this study was to evaluate the opportunity to use CPI method as a cumulative pollution evaluation tool in air quality monitoring by doing measurements of cumulative effect in several air quality measurement stations in two cities of Latvia – Liepaja and Riga. Results show that Cumulative Pollution Index method is not only usable in air quality monitoring as a tool for cumulative effect evaluation, but can reveal new facts about air pollution and ways how it affects human and ecosystem health, – such climatic and environmental factors as humidity and temperature are more important than interactions between individual pollutants and can be considered main elements in forming of cumulative pollution impact.
Key words: air pollution, cumulative effect, bioindication, Cumulative Pollution Index.

Introduction

Air pollution is one of the most actual environmental problems in the world. Increasing traffic density and energy consumption lead to increased pollution causing substances emissions in ambient air. It is a significant risk factor for multiple health conditions, including lung cancer, respiratory and heart diseases. Therefore, it is important to keep up with the latest data about the actual air quality to react timely and initiate appropriate environment management procedures when the pollution levels rise too high (Snyder et al., 2013).

For these purposes, air quality monitoring is carried out. It is a regular and continuous collection of information about air quality to prevent hazards associated with pollution. Usually, as a monitoring technical solution, automated measurement stations are used. They measure concentrations of various substances in nonstop mode – ranging from gaseous pollutants, like nitrogen oxides (NOx) and ozone, to particulate matter. Results are compared according to normative standards to determine if the actual pollution level is a threat or not. However, one thing is to control individual substances – another is the actual impact, caused by synergy of different pollutants and environmental factors. Latest research shows that there exists a hidden threat called cumulative effect – synergy between different pollutants and environmental factors which produce greater impact on living organisms than the same substances in separate action. For example, ozone mixing with other pollutants leads to increased effect on human health (Mauderly and Samet, 2009). Such cumulative effects are very complex and depend on many factors – weather, seasonality, exposure duration, etc. (Stylianou and Nicolich, 2009; Su et al., 2012). Therefore, it is hard to evaluate them.

As cumulative risk assessment of real-world mixtures is hindered by a lack of verified analytical frameworks (Callahan and Sexton, 2007), there are only a few methods for cumulative pollution evaluation. They are relatively simple and use statistical models with a small fixed number of pollutants in association with different factors. An example of such methods is Su et al. (2009) cumulative environmental hazard inequality index (CEHII) which assesses exposure to multiple air pollutants within different racial-ethnic groups and socioeconomic positions in Los Angeles. Another approach is the definition of cumulative pollution as a difference of living organisms' health and measurement results in the same pollution level as it is done in Cumulative Pollution Index (CPI) method – a solution designed for cumulative effect calculation from bioindication and air quality measurement data (Kalniņš, 2012).

Bioindication is a pollution evaluation method which uses living organisms as indicators of pollution level and environmental quality. By applying methods of bioindication, it is not possible to make measurements of air pollutant concentrations as with sensors, though it is an effective tool to evaluate exposure, dose and bioaccumulation – factors which are directly related to cumulative effects. On the contrary, air quality measurements is the main source of information about pollution causing substances in the air – they can't determine measured pollutants'

effect on living organisms, but they can detect individual pollutants and their amount in ambient air (Snyder et al., 2013).

By merging these two approaches – measurements and bioindication, on-site measurements of cumulative effects can be done. However, CPI method is completely new and has never been used in the air pollution evaluation activities (Kalniņš, 2012).

Therefore, the objective of this study was to evaluate the opportunity to use CPI method as a cumulative pollution evaluation tool in air quality monitoring by doing parallel measurements of cumulative effect in several air quality measurement stations in Latvia.

Materials and Methods

The study was carried out in three Latvian national air quality monitoring network sites, where automated measurement stations are placed:

In forest, near the ruins of South fortification of Liepaja (56° 28'48,41''N; 21° 00'01,06''E), in weight and size as similar as possible, lichen samples were collected and placed in perforated plastic containers – then delivered to the chosen air quality measurement sites and placed on automated monitoring stations in height of measurement equipment. To protect lichens from external factors during the transportation, perforated containers were placed into another – airtight containers. Sampling site was chosen according to the pollution dispersion modelling done by the municipality of Liepaja, which shows that on this site the air quality can be described as clean city air (Estonian, Latvian & Lithuanian Environment, 2004).

Three lichen species were used: foliose lichens *Xanthoria parietina* and *Parmelia sulcata* as well as fruticose lichen *Ramalina fraxinea*. They were chosen from different sensitivity groups to exclude specific responses to individual pollutants and environmental factors:

- *Ramalina fraxinea* – sensitive to almost all air pollutants (Nimis et al., 2002);
- *Parmelia sulcata* – intermediate SO_2 tolerant (Peterson et al., 1992; Hawksworth and Rose, 1970) while sensitive to other pollutants, for example, O_3 (Peterson et al., 1992; Ross and Nash, 1983);
- *Xanthoria parietina* – pollution tolerant species which is absent only in high pollution levels (Hawksworth and Rose, 1970; Perkins and Millar, 1987b).

The duration of the study was 12 months – from 01.02.2013. to 01.01.2014.

Chemical analysis of lichen samples

Each month, the containers with samples were removed from the monitoring stations, placed in airtight containers again and delivered to the Laboratory of Plant Biochemistry, Institute of Soil and Plant Science, Latvia University of Agriculture.

As it is possible to determine the pollution impact on lichens by chlorophyll and pheophytin ratio (Riddell et al., 2012; Tretiach et al., 2007; Hauck et al., 2003), and this approach is used in the CPI method, in the laboratory these biochemical values were measured with spectrophotometer Perkin Elmer Lambda 25.

For extraction of both necessary pigments, lichen samples were weighted, placed in 5 ml Dimethylsulphoxide (DMSO) and heated at a temperature of 65 °C for 45 minutes. Then the obtained solution was cooled, inserted in a spectrophotometer, and measured chlorophyll and pheophytin optical densities – 415 and 435 nm wavelengths, according to Ronen and Galun method (1984). To ensure that heavier and greater lichens with more pigment content do not influence the results, they are expressed in weight per optical density of solution (g/OD).

Table 1

Automated air quality measurement stations, used in cumulative pollution evaluation

Monitoring site	Coordinates	Measurement technology	Measured pollutants
Riga, Brivibas street 73	56°57'32", 24°07'34,03"	DOAS*; OPSIS/SM200 „ADAM"	SO_2, NO_2, O_3, benzene, toluene, PM10, PM2.5, Pb, Cd, Ni, As, Benzo(a)pyrene, PAO
Riga, Valdemara street 18	56°57'27,0", 24°06'57,05"	HORIBA traffic pollution measurement station	NO_2, NOx, NO, O_3, CO, PM10, benzene, toluene
Liepaja, Kalpaka street 34	56°31'31'', 21°00'13''	DOAS*; OPSIS/SM200 „ADAM"; HORIBA; diffusion tube	SO_2, NO_2, NO, O_3, CO, benzene, toluene, PM10, PM2.5, Pb, Cd, Ni, As

* Differential Optical Absorption Spectroscopy

CPI index calculation

Using the CPI method, cumulative effect is calculated as index from bioindicator samples health condition and air pollution measurement data using CPI equation (Kalniņš, 2012) with latest additions (2014) which makes it compatible with chlorophyll and pheophytin ratio approach:

$$CPI = \frac{\left\{\left[\left(\sum_1^{ns} P\right)/\left(\sum_1^{ns} C\right)\right]\times 100\right\}}{\left\{\left[\left(\sum_1^{np} C_p\right)/\left(\sum_1^{np} BP_p\right)\right]\times 100\right\}} \quad (1)$$

where:
CPI – cumulative pollution index;
Cp – concentration of pollutant p;
BPp – breakpoint of pollutant p concentration (according to normative);
np – number of pollutants;
ns – number of lichen samples;
C – total amount of chlorophyll and pheophytin in sample;
P– pheophytin amount in sample.

The obtained chlorophyll and pheophytin values are placed in equation 1. (sum of g/OD 435 and 415 nm as C; g/OD 415 nm as P) and together with the air quality measurement data calculated CPI index value.

It is relative, unitless value – the further from 1 as the point of equality between pollution and according to health condition, the greater cumulative impact. Since lichens are living organisms, there are possibilities of natural, pollution not-related pigment changes in them, and therefore, according to the instructions of CPI method usage, it is advisable to determine the threshold value when exceeding it the result is considered as detection of cumulative effect. In this study, as the threshold was chosen value 1 – base threshold, as it is described in CPI mathematical model (Kalniņš, 2012).

Results and Discussion

In this study, from all measured pollutants, 4 were used – SO_2, NO_2, O_3, CO, because they have clearly defined breakpoint values as they are specified in the main air quality normative act in Latvia – Cabinet Regulation No. 1290 „Regulations Regarding Ambient Air Quality" (as of 03.11.2009). Other pollutants, such as benzene and toluene have only breakpoint values related to calendar year, therefore their compliance with the air quality standards can't be evaluated in short term study like this.

According to measurement specifics and data accessibility, SO_2, NO_2, O_3 were used in cumulative impact evaluation process in Liepaja and Brivibas street, and SO_2, NO_2, O_3, CO in Valdemara street. Results – the obtained CPI values – are shown in Table 2.

In Liepaja the threshold is exceeded regularly with peak value in July. A bit different, but similar situation is in Brivibas street, Riga – threshold is exceeded in February and summer months, starting from June and ending in September. The peak is also in September and later CPI values gradually slip below the threshold (Fig 1.).

Results from Valdemara street are completely different – February also is above the threshold, but

Table 2

Monthly measured Cumulative Pollution Index (CPI) values

Month	Measurement place		
	Liepaja	Riga, Valdemara str.	Riga, Brivibas str.
February	1.273	1.140	1.077
March	1.008	0.844	1.009
April	1.106	0.879	0.966
May	1.104	0.877	0.968
June	1.094	0.742	1.308
July	1.393	0.940	1.309
August	1.222	0.928	1.086
September	1.105	0.915	1.507
October	1.142	0.801	1.061
November	1.194	1.449	1.028
December	1.159	1.361	0.976
January	1.054	1.077	0.965

CPI values are unitless – greater number means greater cumulative impact

further cumulative effect is not detected; then, in November there is a peak and the cumulative effect decreases towards January. It is interesting that in some months – June and October, – CPI value is significantly lower than the threshold. As it is unlikely that in some circumstances the air pollution can become more health-friendly, this can rather be associated with natural changes in the amount of pigments in lichens. Therefore, it confirms the need for threshold approach in using CPI method.

In both cities Liepaja and Riga, the cumulative effect maximum is observed in summer months, except Valdemara street, where the CPI peak value is in November (Fig 1.). Therefore it is possible to propose a hypothesis that two of the main cumulative effect building factors are humidity and temperature, because in summer rainfall usually is higher and the air temperature also is significantly higher than the rest of the year. The fact that the cumulative effect in Liepaja is above the threshold almost all year, indirectly confirms this assumption, because due to closeness to large water masses - the Baltic Sea, Trade Channel and the Lake of Liepaja, the daily average relative humidity in the city is one of the highest in Latvia – 82%.

To determine the exact cause of observed cumulative impact variations, a more detailed and larger scale research is needed.

To better understand the obtained results and cumulative pollution forming factors, the CPI values can be viewed by their components separately – comparing bioindication measurement results with the overall pollution level changes (Fig 2.). Figure consists of two kinds of values – 'pollution level' which is

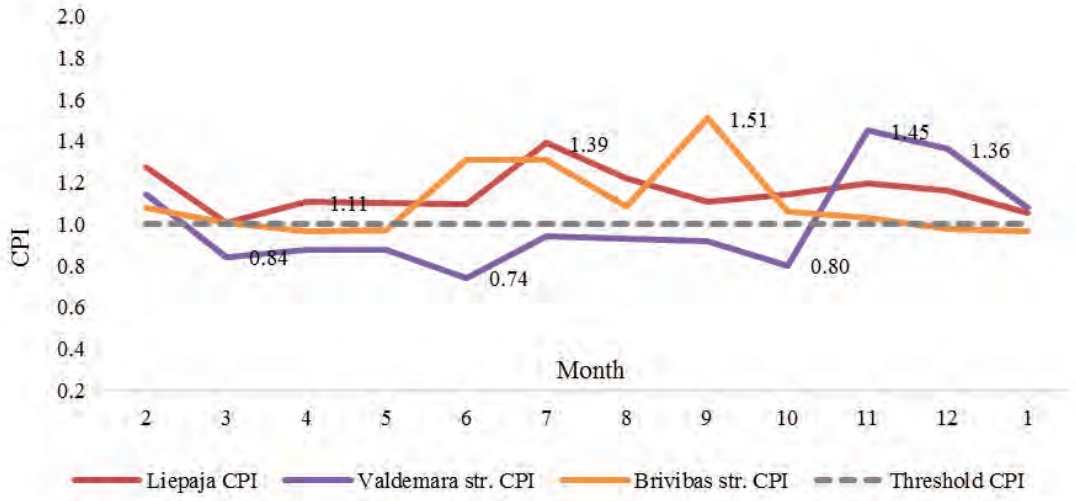

Figure 1. Monthly Cumulative Pollution Index values comparison with threshold (with numbers, only extreme values are shown).

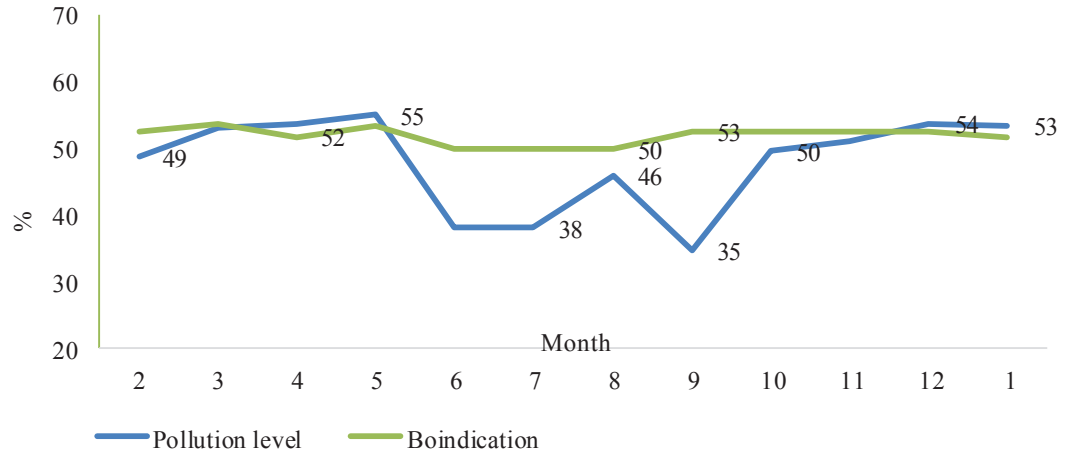

Figure 2. Variation of Cumulative Pollution Index forming components. Results from Brivibas str. in Riga (with numbers, only extreme values are shown).

measured values percentage from breakpoints, and 'bioindication' which is chlorophyll percentage from the total chlorophyll and pheophytin amount.

Such a comparison shows that the air quality measurement data and living organisms' health in the same pollution level not always are the same – often they vary independently from each other. For example, in results from Brivibas street, there are two points when the pollution measurement results are quite opposite to the bioindication data – in August the overall pollution level rises, while its impact on the indicator organisms do not change (pollution level from 38 to 46%; bioindicators damage the same 50%). In September, on the contrary, the pollution level decreases while its impact slightly increases (pollution level 35%; bioindicators damage 53%).

The overall trend in this example (Fig 2.) is that the pollution impact is relatively steady, while pollution causing substances concentrations in ambient air vary in relatively large range. It again raises assumption that in the cumulative pollution evaluation the climate and environmental factors play a more important part than previously known, and the interactions between individual pollutants is only a small part in the cumulative impact structure.

Therefore, it can be concluded that the Cumulative Pollution Index method is not only usable in air quality monitoring as a tool for cumulative effect evaluation, but can reveal new, previously unknown facts about air pollution and ways how it affects human and ecosystem health.

Conclusions

1. During the study, the cumulative effect in Liepaja air quality monitoring site is detected all year long, except in April, while in Riga only in summer (Brivibas str., June to October) and some autumn months (Valdemara str., November to December).
2. In both cities – Liepaja and Riga, the cumulative effect maximum (CPI value 1.3 – 1.39) is observed in summer months, therefore it is possible to propose a hypothesis that two of the main cumulative effect forming factors are humidity and temperature.
3. The study demonstrates the importance of climatic and environmental factors over interactions between individual pollutants as the main elements in building of cumulative air pollution impact – in some months living organisms' health worsens more than increases the overall pollution level (pollution level 35%; bioindicators damage 53% – in September in Brivibas str., Riga).
4. To determine the exact causes of cumulative impact variations, a more detailed and larger scale research is needed.
5. Cumulative Pollution Index method is usable in air pollution monitoring, because it can detect not only the cumulative impact, but can also reveal new facts about the air quality, thus improving understanding about pollution and its impact on living organisms.

References

1. Callahan M.A., Sexton K. (2007) If cumulative risk assessment is the answer, what is the question?. *Environmental Health Perspectives*, 115, pp. 799 – 806.
2. Estonian, Latvian & Lithuanian Environment (2004) Gaisa kvalitātes Liepājas pilsētā sākotnējais novērtējums (Initial assessment of air quality in city of Liepaja). 92 lpp. (in Latvian).
3. Hauck M., Paul A., Gross S., Raubuch M. (2003) Manganese toxicity in epiphytic lichens: chlorophyll degradation and interaction with iron and phosphorus. *Environmental and Experimental Botany*, 49, pp. 181 – 191.
4. Hawksworth D.L., Rose F. (1970) Qualitative scale for estimating sulfur dioxyde air pollution in England and Wales using epiphytic lichens. *Nature*, 227, pp. 145 – 148.
5. Kalniņš V. (2012) Bioindication based cumulative effect evaluation for air pollution monitoring in cases when monitored pollutant values do not exceed breakpoint values. *Innovations and Technologies News*, 2, pp. 3 – 10.
6. Nimis P.L., Scheidegger C., Wolseley P.A. (2002) *Monitoring with Lichens – Monitoring Lichens: NATO science series IV: Earth and Environmental Sciences*, vol. 7, Springer, London, UK, 424 p.
7. Perkins D.F., Millar R.O. (1987) Effects of airborne fluoride emissions near an aluminium works in Wales: part 2 - saxicolous lichens growing on rocks and walls. *Environmental Pollution*, 48, pp. 185 – 196.
8. Peterson J., Schmoldt D., Peterson D., Eilers J., Fisher R., Bachman R. (1992) *Guidelines for Evaluating Air pollution Impacts on Class I Wilderness Areas in the Pacific Northwest. USDA-Forest Service Pacific Northwest Research Station General Technical Report PNW-GTR-299*, 83 p.
9. Riddell J., Padgett P.E., Nash T.H. (2012) Physiological responses of lichens to factorial fumigations with nitric acid and ozone. *Environmental Pollution*, 170, pp. 202 – 210.
10. Ronen R., Galun M. (1984) Pigment extraction from lichens with dimethyl sulfoxide (DMSO) and estimation of chlorophyll degradation. *Environmental and Experimental Botany*, 24, pp. 239 – 245

11. Ross L.J., Nash T.H. (1983) Effect of ozone on gross photosynthesis of lichens. *Environmental and Experimental Botany*, 23, pp. 71 – 77.
12. Snyder E.G., Watkins T.H., Solomon P.A. (2013) The Changing Paradigm of Air Pollution Monitoring. Environmental Science & Technology, 47, pp. 11369 – 11377.
13. Stylianou M., Nicolich M.J. (2009) Cumulative effects and threshold levels in air pollution mortality: Data analysis of nine large US cities using the NMMAPS dataset. *Environmental Pollution*, 157, pp. 2216 – 2223.
14. Su J.G., Jerrett M., Morello-Froch R., Jesdale B.M., Amy D.K. (2012) Inequalities in cumulative environmental burdens among three urbanized counties in California. *Environment International,* 40, pp. 79 – 87.
15. Su J.G., Morello-Frosch R., Jesdale B.M., Kyle A.D., Shamasunder B., Jerrett M. (2009) An index for assessing demographic inequalities in cumulative environmental hazards with application to Los Angeles, California. *Environmental Science & Technology*, 43, pp. 7626 – 7634.
16. The Cabinet of Ministers of the Republic of Latvia (03.11.2009) Cabinet Regulation No. 1290 „Regulations Regarding Ambient Air Quality". Available at: http://likumi.lv/doc.php?id=200712, 20 February 2014.

ECOLOGICAL FARMING IN AUKŠTADVARIS AND KREKENAVA REGIONAL PARKS

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Abstract
Ecological farming is relevant to protected areas. The aim of the study is to perform an analysis of farms applying organic farming measures as well as the analysis of the change of their areas in Aukštadvaris and Krekenava regional parks (RP).
The object of the investigation - the farms of Aukštadvaris and Krekenava regional parks.
The study is carried out to determine how many farms, forming the regional parks' territory, are managed according to the principles of organic farming. The change of the above- mentioned farming area for 2009-2011 is analyzed as well. Paluknys and Naujamiestis subdistricts, not incorporated into the territory of regional parks, were chosen for the comparison analysis.
The analysis of the 2009 – 2011 period showed that the declared areas in Krekenava RP have decreased, and the area of farms applying organic measures has increased by 81.69 hectares (nearly 2.5 times). The number of organic farms increased by 1.5 times in Aukštadvaris RP over the period of 2009-2011, and the area has increased by 187.36 ha. The percentage calculations revealed that in 2011 the area of farms applying organic farming measures in Aukštadvaris RP made up 18.89 per cent of the total area declared, the number of farms - 6.61 per cent. The area of farms applying organic farming measures in Krekenava RP was only 1.71 per cent, measures were applied only by 1.89 per cent of all the declared.
Key words: protected areas, regional park, declared areas, ecological farming measures.

Introduction

Ecological or environmental farming is a conservation measure that protects the environment and a perspective farming branch, supported by the European Union. European Union's Common Agricultural Policy is oriented to the organic farming, which provides environmental and social-economical benefits.

Organic farming is a form of agriculture that relies on techniques such as crop rotation, green manure, compost, and biological pest control. Depending on whose definition is used, organic farming uses fertilizers and pesticides (which include herbicides, insecticides and fungicides) if they are considered natural (such as bone meal from animals or pyrethrin from flowers), but it excludes or strictly limits the use of synthetic petrochemical fertilizers and pesticides; plant growth regulators such as hormones; livestock antibiotics; genetically modified organisms (Directorate, 2013); human sewage sludge; and nanomaterials (Paull, 2011).

Organic farming is important because conventional agriculture - which involves high-yielding plants, mechanized tillage, synthetic fertilizers and biocides - is so detrimental to the environment. For instance, fertilizer runoff from conventional agriculture is the chief culprit in creating dead zones–low oxygen areas where marine life cannot survive. Proponents of organic farming argue that conventional farming also causes soil erosion, greenhouse gas emission, increased pest resistance and loss of biodiversity (Grandi, 2010; Triantafyllidis, 2010). The aims of organic farming are to protect: the environment, by using organic management practices that do not have the adverse effects of conventional practices, and the health of consumers, by the provision of organic products (Argyropoulos et al., 2013).

The number of organic farms across Europe has been increasing since 1990. The growing demand for organic products has accelerated the growth of organic farming in Europe, and the development of organic farms is determined by the financial support from the EU funds.

One of the reasons determining an increasing number of organic farms is the EU's state support. From support measures (direct and compensatory payments), allocated to organic farms, the greatest impact have benefits for the certified area used for organic farming and food production (Kazakevičius, 2010).

Protected areas are considered to be an important instrument ensuring general ecological balance of the countryside in the presence of intensive farming.

Ecological farming and environmental measures are very important for the sensitive and vulnerable plant and animal species and habitats.

The intensification and expansion of modern agriculture is amongst the greatest current threats to worldwide biodiversity (Hole et al., 2005).

The object of the investigation – the farms of Aukštadvaris and Krekenava regional parks.

The aim of the investigation is to perform analysis of farms applying organic farming principles as well as the analysis of the change of their areas in Aukštadvaris and Krekenava regional parks (RP).

Tasks of the investigation:

1. To characterize Aukštadvaris RP and Krekenava RP.
2. To analyze the numbers and the declared areas of the farms applying organic farming methods in Aukštadvaris RP and Krekenava RP.
3. To perform the comparison analysis with the Regional Parks and subdistricts, situated outside the territory of the parks.

Materials and Methods

Comparative, analytical as well as statistical and logical analysis methods were used during the investigation.

The study was carried out to determine how many farms, forming regional parks‘ territory, apply organic farming measures. The change of the above-mentioned farms area for 2009-2011 was analyzed as well. Paluknys and Naujamiestis subdistricts, not incorporated into the territory of regional parks, were chosen for the comparison analysis.

The analysis of the agricultural lands in Aukštadvaris regional park and Paluknys, Naujamiestis subdistricts was carried out following the data of the Agriculture information and rural business center on the declared areas of agricultural lands.

Results and Discussion

Analysis of the current situation in Aukštadvaris and Krekenava regional parks

Nowadays the protected areas occupy some 10 percent of the Earth’s surface, in a landscape dominated by the agricultural sector. Even within certain protected area categories, much land is used for agriculture (i.e. 30 percent of categories V and VI). More importantly, connecting areas between protected areas run through croplands, pastures and forests - which globally occupy over 60 percent of the Earth’s surface. Clearly, relationships with the inhabitants of these areas are fundamental to their management (Grandi, 2010; Triantafyllidis, 2010).

The national network of protected areas in Lithuania covers 1,021,471.16 ha and makes 15.64 per cent of the total area of the country (Saugomų, 2012). The regional parks in Lithuania cover 449,363.59 ha and make 44 per cent of the total area of the protected areas and 6.88 per cent of the country. There are 30 regional parks in Lithuania (Overview, 2013).

Aukštadvaris regional park is situated in southeastern Lithuania, in the most remarkable part of the Dzūkai upland. Almost entire territory is situated in the Trakai district. Only a small northwestern part belongs to the Prienai and Kaišiadorys districts. The area of the regional park covers 17,032.43 ha, in which Mergiškiai nature reserve (covering the area of 157 ha) is situated. There are 15 reserves in Aukštadvaris regional park.

27 territories correspond to the criteria of the habitats of European importance (Ivavičiūtė, 2011).

The largest area is occupied by the functional priority zone – the territory of reserves covering 61.95 percent of the whole park’s territory, and the ecological protection priority zone, covering 23.09 per cent of the whole park’s territory (Table 1).

The agricultural lands in Aukštadvaris RP make up 38.09 percent of the whole park’s territory (Aukštadvario, 2013) (Table 2).

Agricultural land productivity (quality) score describes agricultural conditions best of all. The average efficiency of the agricultural lands in Trakai district is 33.4 scores, i.e. is lower than the average point of Lithuania (39.1).

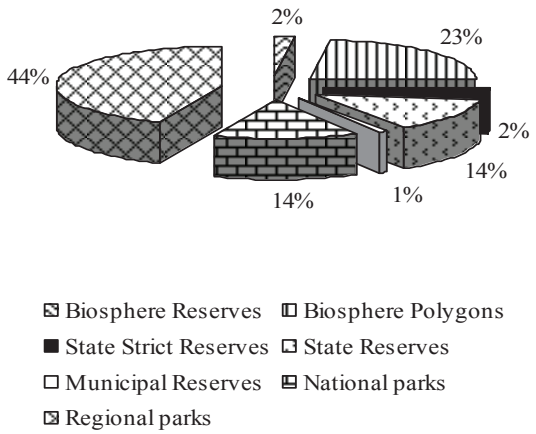


Figure 1. Proportion of protected areas by types (Proportion, 2013).

Table 1

The areas of the functional priority zones of Aukštadvaris regional park

Number	The name of the functional priority zone	Area, ha	Percent from the RP area
1	Conservation priority zone - reserve	156.39	0.92
2	Conservation priority zone - parks	10,551.10	61.95
3	Ecological protection priority zone	3,932.69	23.09
4	Recreational priority zone	1,474.29	8.66
5	Economic priority zone	692.64	4.06
6	The living zone	225.32	1.32
Total:		**17,032.43**	**100**
The area of the buffer protection zones		6,839.62	-
Total area		**23,872.05**	-

Table 2

Distribution of agricultural lands in Aukštadvaris RP

Number	Agricultural lands	Area, ha	Percent
1	Agricultural lands	6,487.27	38.09
2	Forest area	8,707.36	51.12
3	Water bodies	1,299.30	7.63
4	Swamps	94.00	0.55
5	Other	6.04	0.04
Total:		**17,032.43**	**100**

Aukštadvaris RP is located in jauric areas in which, although less dominated by soils affected by jauric processes, the averagely podzolized soils share a considerable part of them. From the agricultural point of view, these are soils of lower productivity with significantly lower conventional crop yields. These farmland soils, usually of a lighter granulometric composition, are distinguished by light vulnerability of agro-ecosystems as well as by sensitivity to the use of various agrochemicals - modern intensive farming measures.

Thus, the presence of protected areas in them is very logical, because one of the objectives of the establishment of regional parks is the promotion of organic farming. A variety of recommendations on how to farm in unfertile areas, indicating that the most rationally is to plant forest plantations, to develop non-traditional businesses, rural tourism and others, are prepared (Marcinkonienė et al., 2010).

Paluknys subdistrict, situated outside the territory of Aukštadvaris RP, was chosen to perform the comparative analysis. Paluknys subdistrict, situated in the southeastern part of the Trakai district, was chosen for the comparison of the use of agricultural lands in Aukštadvaris regional park. The territory covers the area of approximately 14 thousand ha. A part of the inhabitants upholds the traditional agriculture.

The average efficiency of the agricultural lands in Paluknys subdistrict is 31.8 points.

Characterization of Krekenava Regional Park

Almost entire park's territory is situated in the Panevėžys district municipality of Panevėžys County,

Table 3

The areas of the functional priority zones of Krekenava regional park

Number	The name of the functional priority zone	Area, ha	Percent from the RP area
1	Conservation priority zone - reserve	4,089.9	35.3
2	Ecological protection priority zone	538.6	4.6
4	Recreational priority zone	266.7	2.3
5	Economic priority zone	6,582.2	56.8
6	The living zone	112.3	1.0
Total:		**11,589.7**	**100**

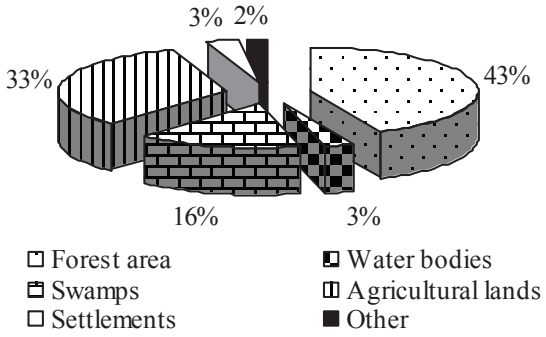


Figure 2. Distribution of agricultural lands in Krekenava RP, percent.

only the south-western edge marginally intervenes into the Kėdainiai district municipality of Kaunas County.

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 Nevėžis river valley, its natural ecosystem and cultural heritage treasures, to look after them and use rationally (Ivavičiūtė, 2011).

The largest area of Krekenava RP is occupied by the functional priority zone – Economic priority zone 56.8 percent of the whole park's territory.

The ecological protection priority zone covers 4.6 percent of the whole park's territory (Table 3).

Agricultural farming lands make up 33.0 percent of the Krekenava Regional Park's territory (Raudonytė, 2009) (Fig. 2).

The average productivity of soils of agricultural farming lands in the Panevėžys district municipality is 47.5 scores. The average productivity of the agricultural farming lands situated in the park is higher than 45 scores.

The Naujamiestis subdistrict was chosen for the comparison of the use of agricultural lands and ecological farming in Naujamiestis and regional park. The territory covers the area of approximately 15.6 thousand ha. There are 66 villages in the subdistrict, 4 agricultural companies and agricultural cooperatives (Naujamiesčio, 2013).

The average efficiecy of the agricultural lands in Naujamiestis subdistrict is 50.6 scores.

Thus, for the fulfillment of analysis the following regional parks, situated in different regions of Lithuania, were chosen: Aukštadvaris RP in eastern Lithuania, Krekenava RP – in central Lithuania.

In the aforementioned parks the land productivity is also different: in Aukštadvaris RP the land productivity is below 35 scores (Paluknys subdistrict - 31.8 scores), while the soils of Krekenava RP are much more efficient (in Panevezys district - 47.5, in Naujamiestis subdistrict - 50.6).

Having performed the analysis of the distribution of land use in parks, it was found that agricultural land in Aukštadvaris RP makes up 38.09 per cent, in Krekenava RP - 33 per cent of the parks' land area.

Ecological farming in Aukštadvaris and Krekenava regional parks

The performed comparative analysis of the declared farm areas in **Aukštadvaris RP** shows that the total farm area decreased by 1,058.13 ha (Fig. 3) and the number of those declaring their farms decreased by 142 farms.

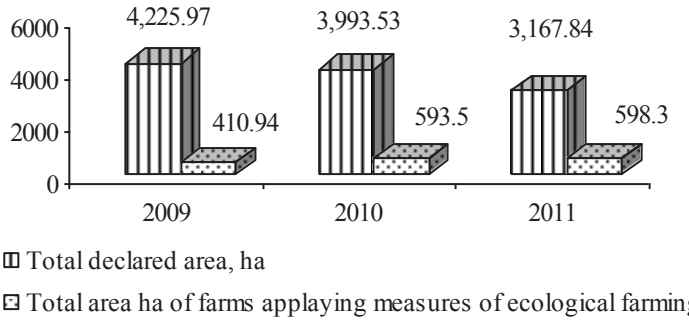
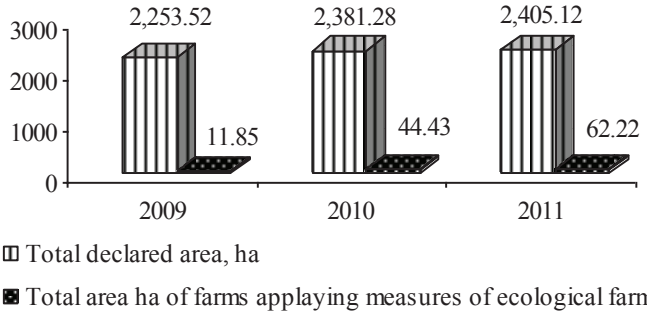


Figure 3. Analysis of the declared areas change in Aukštadvaris RP during the period of 2009 – 2011.



Fiure 4. Analysis of the declared areas change in Paluknys subdistrict during the period of 2009 – 2011.

In 2009, the total area of declared farms made up 24.81 per cent of the total Aukštadvaris RP area, in 2010 – 23.45 per cent, in 2011 – 18.16 per cent.

The number and area of farms applying organic farming measures increased each year. In 2009, these measures were applied by 3.47 per cent of the declared farmers in the 410.94 ha area, and it made up 9.72 per cent of the total area declared and only 6.33 per cent from RP's agricultural land area. In 2011, 6.61 per cent of farmers applied organic farming measures in the area of 598.3 ha (18.89 per cent of the total area

declared and 22.9 per cent from the RP's agricultural area). So, the number of organic farms increased by 1.5 times in Aukštadvaris RP over the period of 2009 – 2011, and the area has increased by 187.36 ha.

In Paluknys subdistrict, unlike Aukštadvaris RP, the total area declared gradually increased for the period of 2009-2011 (Fig. 4), but the number of farms, which have submitted declarations, decreased by 19 farms. Only one farmer applied organic farming measures in the analyzed municipality in 2009 in the area of 11.85 ha. It made up 0.53 per cent of the total area declared.

The number farms applying these methods, rose slightly - by one during one year period, and the area has increased to 66.22 ha and made up 2.59 per cent of the total area declared. So, the number of organic farms in Paluknys subdistrict increased almost 6 times or by 50.37 ha in 2009 – 2011.

The number of farms, which submitted declarations, as well as the area declared in **Krekenava RP**, decreased in 2009-2011.

In 2009, 424 farmers submitted declarations and declared the area of 8,502.08 hectares, or 73.36 per cent of the total area of Krekenava RP (Fig. 5).

In 2010, the declared area increased by 2.92 hectares, but the number of declared farms decreased by 5 farms. In 2011, 371 farmers declared the area of 8,184.19 hectares, which made up 70.62 of the total area of RP. Thus, during the period of 2009-2011 the number of declared decreased by 317.89 hectares.

Only 4 farmers (0.94 per cent of all who had declared) applied organic farming measures in the area of 58.6 ha in Krekenava regional park in 2009. It made up just 0.69 per cent of the total area declared. In 2010, these methods were applied by 6 farmers in the area of 112.71 ha (1.32 per cent from the total area declared), in 2011 – 7 farmers in the area of 140.29 ha (1.71 per cent).

The analysis of the 2009 – 2011 period showed that the declared areas in Krekenava RP have decreased, and the area of farms applying organic measures has increased by 81.69 hectares (nearly 2.5 times).

In Naujamiestis subdistrict both the declared farm areas and the number of farmers, who had submitted

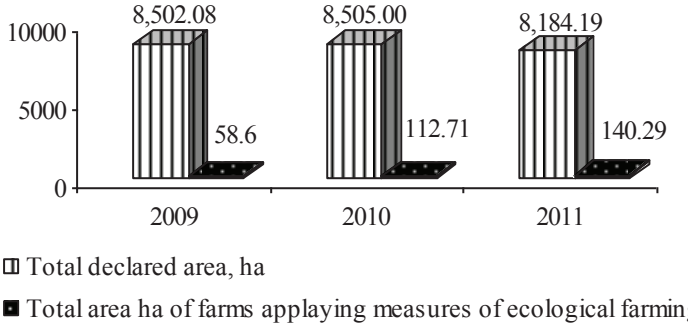


Figure 5. Analysis of the declared areas change in Krekenava RP during the period of 2009 – 2011.

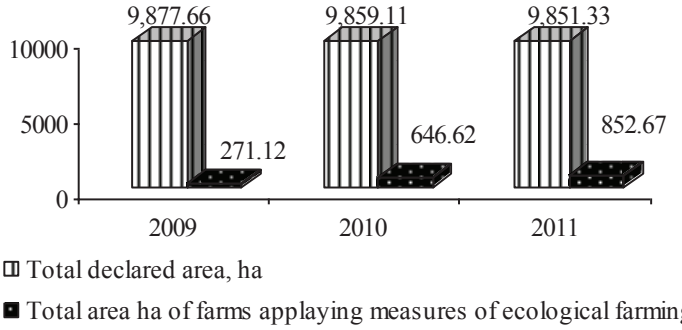


Figure 6. Analysis of the declared areas and farms change in Naujamiestis subdistrict during the period of 2009 – 2011.

declarations in 2009 – 2011, decreased. During the above-mentioned period, the number of farmers applying organic farming measures in Naujamiestis subdistrict has increased twice and 12 farms i.e., 3.63 per cent of the declared had organic farms in 2011.

In 2009, the area of 271.12 ha (2.74 per cent of the total area declared), in which organic farming measures were used, was declared in the subdistrict (Fig. 6).

In 2010, the area increased to 646.62 ha (6.56 per cent of the total area declared), in 2011 - up to 852.67 and made up 8.66 per cent. During the period of 2009 – 2011, the analyzed area increased by 581.55 hectares or 3 times.

The analysis of Aukštadvaris RP and the Paluknys subdistrict (which is not incorporated into the park‘s territory) as well as Krekenava RP and Naujamiestis subdistrict of 2009-2011 showed that organic farming has been introduced at the number of farms and the area has increased. The percentage calculations revealed that in 2011 the area of farms applying organic farming measures in Aukštadvaris RP made up 18.89 per cent of the total area declared, the number of farms - 6.61 per cent. In Paluknys subdistrict - 2.59 and 1.55 per cent, respectively.

The area of farms using organic farming methods in Krekenava RP was only 1.71 per cent, methods were applied only by 1.89 per cent of all the declared. Meanwhile, the percentage in Naujamiestis subdistrict, which is not incorporated into the area of Krekenava RP, is distributed as follows: 8.66 per cent of the total area declared and 3.65 per cent from the number of farms that submitted declarations. It was thus found that the area of the farms applying organic farming measures in Krekenava regional park is the smallest compared to Naujamiestis subdistrict and Aukštadvaris RP, although one of the activities promoted in Krekenava RP is organic farming.

Organic farming, clearly a viable option in many situations, is still not fully exploited and is not wide spread in protected areas. Organic farming is important because the conventional agriculture - which involves high-yielding plants, mechanized tillage, synthetic fertilizers and biocides - is so detrimental to the environment.

Conclusions

1. The national network of protected areas in Lithuania covers 1,021,471.16 ha and makes 15.64 percent of the total area of the country. The regional parks in Lithuania cover 449,363.59 ha and make 44 percent of the total area of the protected areas and 6.88 percent of the country.
2. The largest area of Aukštadvaris RP is occupied by the functional priority zone – the territory of reserves covering 61.95 percent of the whole park’s territory, and the ecological protection priority zone, covering 23.09 percent of the whole park’s territory.
3. The largest area of Krekenava RP is occupied by the functional priority zone – Economic priority zone 56.8 percent of the whole park’s territory. The ecological protection priority zone covering 4.6 per cent of the whole park’s territory.
4. The number of organic farms increased by 1.5 times in Aukštadvaris RP over the period of 2009 – 2011, and the area has increased by 187.36 ha. The number of organic farms in Paluknys subdistrict increased almost 6 times or by 50.37 ha in 2009 – 2011.
5. The analysis of the 2009-2011 period showed that the declared areas in Krekenava RP have decreased, and the area of farms applying organic measures has increased by 81.69 hectares (nearly 2.5 times). The number of farmers applying organic farming measures in Naujamiestis subdistrict has increased twice and 12 farms i.e., 3.63 per cent of the declared had organic farms in 2011, the analyzed area increased by 581.55 hectares or 3 times.
6. The percentage calculations revealed that in 2011 the area of farms using organic farming methods in Aukštadvaris RP made up 18.89 per cent of the

total area declared, the number of farms - 6.61 per cent. In Paluknys subdistrict - 2.59 and 1.55 per cent, respectively.

7. The area of farms applying organic farming measures in Krekenava RP was only 1.71 per cent, measures were applied only by 1.89 per cent of all the declared. Meanwhile, the percentage in Naujamiestis subdistrict, which is not incorporated into the area of Krekenava RP, is distributed as follows: 8.66 per cent of the total area declared and 3.65 per cent from the number of farms that submitted declarations.

References

1. Argyropoulos Ch., Tsiafouli M.A., Sgardelis S.P., Pantis J.D. (2013) Organic farming without organic products, *Land Use Policy* Volume 32, pp. 324 – 328.
2. Aukštadvario regioninis parkas. (Aukštadvaris Regional Park). Available at: http://www.arp.lt/index.php?psl=106&i=0&d=&klb=1, 5 December 2013. (in Lithuanian).
3. Directorate General for Agriculture and Rural Development of the European Commission. What is organic farming. Available at: http://ec.europa.eu/agriculture/organic/organic-farming/what-organic_en, 5 December 2013.
4. Grandi C., Triantafyllidis A. (2010) *Organic Agriculture in Protected Areas. The Italan Experience.* Natural Resources Management and Environment Department: Rome, 29. p.
5. Hole D.G., Perkins A.J., Wilson J.D., Alexander I.H., Grice P.V., Evans A.D. (2005) Does organic farming benefit biodiversity? *Biological Conservation* 122 (1), pp. 113 – 130.
6. International Federation of Organic Agriculture Movements "Definition of Organic Agriculture". IFOAM. Retrieved 2008-09-30. Available at: http://www.ifoam, 5 December 2013.
7. Ivavičiūtė G. (2011) The Use Of Agricultural Lands In Aukštadvaris Regional Park, *Environmental Engineering*, Vilnius Gediminas Technical University Press Technika ISSN: 2029-7092 online ISBN: 978-9955-28-831-2 CD, pp. 120 – 126.
8. Ivavičiūtė G. (2011) The Use Of Agricultural Lands In Krekenava Regional Park, *Rural Development' 2011*. Akademija ISSN: 1822-3230, pp. 427 – 433.
9. Kazakevičius Z. (2010) Tiesioginės paramos Lietuvos ekologinės gamybos ūkiams efektyvumas (Management theory and studies for rural business and infrastructure development), *Proceedings of the Management Theory & Studies for Rural Business & Infrastructure Infrastructure Development Conference* 20 (1). Research papers. ISSN 1822-6760, pp. 53 – 63. (in Lithuanian).
10. Marcinkonienė A., Marcinkonis M., Armolaitis K. (2010) Neries ir Aukštadvario regioninių parkų ištekliai – žemdirbystei, miškininkystei ir kaimo turizmui. (Neris and Aukštadvaris RP resources – for agriculture, forestry and rural tourism). ISSN 1648-9098. *Ekonomika ir vadyba: aktualijos ir perspektyvos (Economic and Management: Current Issues and Perspectives)* 3 (19), pp. 136 – 140. (in Lithuanian).
11. Naujamiesčio seniūnija. (Naujamiestis subdistrict) Available at: http://www.panrs.lt/go.php/lit/Naujamiescio-seniunija/1263, 5 December 2013. (in Lithuanian).
12. Overview of the system of PA. Available at: www.vstt.lt/en/VI/index.php#r/75, 5 December 2013.
13. Paull J. (2011) Nanomaterials in food and agriculture: The big issue of small matter for organic food and farming. *Proceedings of the Third Scientific Conference of ISOFAR (International Society of Organic Agriculture Research)* 2, pp. 96 – 99.
14. Proportion of protected areas by types. Available at: http://www.vstt.lt/VI/files/File/Statistika/ST%20diagrama%202012%2004%2010%20EN%20max.jpg, 5 December 2013.
15. Raudonytė J. (2009) Ūkinė veikla Lietuvos valstybiniuose parkuose (Economical activity in Lithuanian state parks). *Annales Geographicae*, t. 42 (1-2), pp. 67 – 70. (in Lithuanian).
16. Saugomų teritorijų statistika (2012) Valstybinė saugomų teritorijų tarnyba prie Aplinkos ministerijos. (State Service for Protected Areas under the Ministry of Enviroment). Available at: http://www.vstt.lt/VI/index.php#r/188, 15 December 2013. (in Lithuanian).

FUNCTIONAL CHANGES IN RURAL AREAS IN NORTH-EASTERN POLAND

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Abstract
Rural areas in Poland are characterized by great diversity in their functional spatial structure. Throughout history, their distinct features have been shaped by natural, historical and socio-economic factors. The aim of this study was to analyze the changes in the functional spatial structure of North-Eastern Poland. The analysis involved a comparison of data for 1988 and 2012. Research data was supplied mainly by the Central Statistical Office in Poland. The key drivers of change in the investigated region are agriculture, tourism, forestry and environmentally-friendly industrial processes. The results of the economic and social development are constantly changing in rural areas. Based on analysis, the functional structure of rural areas in North-Eastern Poland between 1988 and 2012 shows that they are more diversified. Over the years, rural areas in North-Eastern Poland were identified with agriculture but now they have multifunctional character.
Key words: Region of Warmia and Mazury, rural areas, functional structure.

Introduction

Rural areas in North-Eastern Poland are characterized by growing levels of functional diversity. The observed changes are stimulated both by external factors, including European integration, and internal factors, mostly natural conditions that play a key role in rural transformation processes. The level of economic development, the availability of technical and social infrastructure and standards of living are also important change drivers in rural areas. An in-depth knowledge of factors and conditions that influence rural development supports the identification of local potential and contributes to rural growth. According to Bański and Stola (2002), ineffective spatial management poses a barrier to local growth and development. For this reason, efforts should be made to implement rational spatial policies that promote sustainable development, economic competitiveness, social and territorial cohesion and environmental protection. This study analyses functional changes in rural areas of North-Eastern Poland between 1988 and 2012. The aim of the analysis was to determine directions for the future development of the evaluated rural areas. The assessment covered rural municipalities in the Region of Warmia and Mazury and the Region of Podlasie. The level of functional development in rural areas in north-eastern Poland in 1988 was determined based on the results of a functional and spatial classification proposed by Stola (1993). The functional and spatial structure of rural areas in North-Eastern Poland in 2012 was assessed in view of the data supplied by the Central Statistical Office. Functional areas within municipalities were identified by using a set of diagnostic features based on which municipalities were divided into five functional types recognized in the 1988 classification system. The results of the analysis will support the identification of the direction of changes in the functional and spatial structure of rural areas in North-Eastern Poland. In line with a general trend, rural areas in Poland are increasingly often transformed into multifunctional areas where farming activities co-exist with non-agricultural activities. The rate and character of functional changes in rural areas have to be identified to ensure that multifunctional development improves living conditions for members of the local community and contributes to the protection of the natural and cultural landscape.

Materials and Methods

Characteristic features of rural areas in North-Eastern Poland

North-Eastern Poland occupies the area of 44360 km^2 and comprises the Region of Warmia and Mazury and the Region of Podlasie. The investigated area borders the Kaliningrad Region, Lithuania and Belarus, and it marks the easternmost boundary of the European Union. North-Eastern Poland is characterized by a high degree of naturalness, diverse relief, an abundance of lakes, extensive forests and rich flora and fauna (Bera, 2013). With the exception of one constituent municipality, North-Eastern Poland is part of the area referred to as the Green Lungs of Poland that covers the most attractive natural sites in the country (Stanny and Czarnecki, 2010; Gwiazdzinska-Goraj and Goraj, 2013).

North-Eastern Poland is renowned for its unique natural features, including:

in the Region of Podlasie:

- Europe's largest swamp complex of unique ecological value in the valleys of rivers Narew and Biebrza and in Narew and Biebrza National Parks,
- valleys of the Bug River with its tributary of Nurzec, the Narew River with its tributary of Supraśl, the Biebrza River with its tributary Pisa, rivers Czarna Hańcza, Rospuda and Szeszupa,

- Suwałki-Augustów Lakeland with the Wigry National Park, the Suwałki Landscape Park and lakes in the area of Rajgród,
- Białowieża Forest with the Białowieża National Park, Knyszyń Forest with the Knyszyń Landscape Park, and the Augustów Primeval Forest,

in the Region of Warmia and Mazury:

- rivers Pasłęka and Łyna and their tributaries that create valleys with steep fluvial terraces,
- dense forest complexes, including the Piska Forest and the Napiwodzko-Ramucka Forest,
- an abundance of lakes in the northern part of the Region of Warmia and Mazury with the largest lakes of Śniardwy, Mamry and Niegocin. The region also features two waterway systems connecting the Great Masurian Lake system and the Warmia Lake system.

Conservation areas account for approximately 40% of the region's territory. The natural features of North-Eastern Poland are recognized for their uniqueness not only in Poland, but also across Europe (Jongman et al., 2004). The Białowieża Forest has been designated a UNESCO Biosphere Reserve. Rural areas in North-Eastern Poland occupy 42830 km^2, they account for 97% of its territory and have a 40% share of the national population. In Warmia and Mazury and as well as in Podlasie, agriculture and food production continue to be the main economic drivers, but the share of non-agricultural activities is expanding steadily. This region is characterized by weak growth dynamics and the occurrence of adverse social consequences of the transformation which is characteristic for problem areas (Bański, 1999; Churski, 2002; Roszkowska-Mądra, 2005). The discussed regions are characterized by low levels of socio-economic development, mainly due to their peripherallocation relative to Poland's key economic hubs as well as their location on the outskirts of the European Union. The establishment of a cross-border traffic zone would significantly contribute to those regions' development.

Functional spatial structure of Poland

Functional spatial structure is determined by both external factors, such as globalization and European integration, and internal factors of historical, natural, cultural, social, economic, legal and political nature. The extent to which those factors contribute to functional spatial structure depends on a region's development potential. The present functional spatial structure of Poland was largely determined by historical events. In the interwar period, the main aim of spatial planning policies was to shift strategic industries to the central part of the country and away from state borders. Poland's spatial structure relied heavily on a network of transport corridors between the key urban areas and two main axes of industrial development intersecting Lower Silesia. The area characterized by the highest level of industrial development and highest capital intensity had the shape of a triangle with vertices in the area of the Tricity, Wrocław and Rzeszów. This scheme led to significant differences in investment levels across the country, and the smallest amounts of capital were channeled to eastern Poland (Bański, 2007). Although various measures had been undertaken to distribute industrial sites more evenly and to promote the development of cities and the settlement network, considerable disproportions still exist between central and western Poland and eastern parts of the country. Poland's spatial planning policies were largely influenced by its EU membership and processes related to European integration, economic cooperation and the EU's foreign policy towards Eastern Europe, South-Eastern Europe and the Middle East. The latter can be attributed to the fact that Poland's eastern border constitutes the external border of the European Union. Economic cooperation between the EU and Eastern Europe offers vast growth opportunities for Poland's eastern regions, and it could give rise to the development of transit infrastructure and large urban centers in Eastern Poland. According to the National Spatial Development Concept 2030, the polycentric character of Poland's metropolitan network with a regular distribution of cities of similar size and a tiered hierarchy structure is the key contributor to the development. A polycentric settlement pattern supports sustainable development, economic competitiveness, social and territorial cohesion and environmental protection. The achievement of the above goals requires measures that support the development of regions situated along Poland's eastern border.

Throughout its history, Poland was a largely agricultural state, and non-agricultural activities involved rudimentary mining, simple processing of extracted minerals and crafts (Stola, 1987; Bański, 2003; Gwiaździńska, 2004). Rural areas had a monofunctional spatial structure, and most inhabitants performed farm work. Qualitative and quantitative changes in farm management and working and living conditions led to gradual diversification of rural areas. According to Stola (1993), in the 1980s, the leading rural activities that catered to external needs were agriculture and forestry in the bioproduction category, industry in the technological category, tourism, recreation and housing in the service category. An analysis of the functional structure of Poland's rural areas points to a predominance of bioproduction activities and services in north-eastern and north-western parts of the country, excluding rural municipalities situated on the outskirts of large urban

and industrial centers. Central, southern and south-western Poland is characterized by a more complex functional structure where technological activities play an equally important or a more important role than bioproduction and service functions, subject to the level of social and economic development in a given region. The social and political transformations initiated in 1989 set new directions for the development of rural areas (Kluvankova-Oravska, 2004). The main focus was shifted to non-agricultural activities at the expense of traditional farming functions. The transformation process necessitated various reforms, including modernization of agriculture and reduction of employment in the farming sector. The relevant measures require greater support, and they have been delineated in the National Spatial Development Concept 2030. Rural areas are characterized by growing functional diversity, and they effectively contribute to sustainable development in Poland (National Spatial Development Concept 2030). Environmental protection and landscape preservation measures will contribute to the spatial and functional cohesion of diverse rural areas. It should be noted, however, that multifunctional development requires rational spatial planning policies.

Methods

Functional spatial changes in Polish rural areas were analyzed based on data covering 1989, the year which marks the beginning of economic and political transformations, and 2012, which illustrates the progress made after Poland's accession to the European Union. Functional spatial changes in North-Eastern Poland were evaluated over a long period of time in between the selected years. The level of functional development that had been attained by rural areas in North-Eastern Poland in 1988 was determined with the use of a functional spatial classification method proposed by Stola (1993). The proposed approach was used to identify 14 functional categories that were combined to produce 5 large groups with a predominance of one or several functions:

1) group with a predominance of agricultural functions;
2) group with an even share of various functions;
3) group with a predominance of forestry functions;
4) group with a predominance of tourist and recreational functions;
5) group with a predominance of industrial functions or highly urbanized areas (Bański, 2003; Goraj and Gwiaździńska-Goraj, 2010).

Functional spatial changes in rural areas of North-Eastern Poland were analyzed in view of 2012 data supplied by the Central Statistical Office. Functional areas in municipalities were identified based on diagnostic features that classified the municipality into one of the five functional categories relevant to the 1988 classification system. The following diagnostic features were adopted on the basis of the literature and our own research:

- area of municipality, 2012;
- population in municipality, 2012;
- working-age population in municipality, 2012;
- number of businesses registered in the REGON system, 2012;
- farmland area, 2010;
- number of farms conducting strictly agricultural activities, 2010;
- number of beds in tourist accommodation establishments, 2012;
- total number of tourist accommodation establishments, 2012;
- forest area in municipality, 2012.

Municipalities were classified into the respective functional categories with the use of the indicators proposed by Stola (1993, 2002), Bański (2002, 2003, 2007), Falkowski (1993), Gwiaździńska (2004) and Gwiaździńska-Goraj and Goraj (2010) based on their threshold values:

- functional group with a predominance of non-agricultural functions: industrial, residential and services:
  - population density, 2012,
  - number of businesses registered in the REGON system per 1000 working-age residents, 2012:
- functional group with a predominance of agricultural functions:
  - share of farmland in total area, 2012,
  - share of farms conducting strictly agricultural activities, 2010;
- functional group with a predominance of tourist and recreational functions:
  - number of beds in tourist accommodation establishments per 1000 residents, 2012,
  - number of tourist accommodation establishments per 100 km^2, 2012;
- functional groups with a predominance of forestry functions:
  - share of forests in the total area of municipality, 2012;
- group with an equal share of various functions:
  - when more than one functional group in a municipality satisfied threshold values.

Results and Discussion

Functional transformations in rural areas of North-Eastern Poland

Throughout its history, Poland was a largely agricultural state, but the socio-economic transformations initiated in 1989 necessitated

Table 1

Functional classification of rural areas in North-Eastern Poland

Group	Functional groups	1988	2012
		Number of municipalities 209	Number of municipalities 209
1	with a predominance of agriculture	109	100
2	with an equal share of different functions	36	87
3	with a predominance of forestry functions	25	7
4	with a predominance of tourist and recreational functions	18	4
5	with a predominance of non-agricultural functions: industrial, residential and services	21	11

the development of non-agricultural functions (Gwiaździńska-Goraj and Jezierska-Thole, 2013).

In 1988, bioproduction functions were the prevalent forms of economic activity in nearly 70% of rural areas in North-Eastern Poland. Agricultural functions were predominant in the Region of Warmia and Mazury (50%) and the Region of Podlasie (54%). Those municipalities were situated in the northern, eastern and western parts of the Region of Warmia and Mazury and the central part of the Region of Podlasie with the most favorable farming conditions. Those areas are characterized by a high share of farmland in total land area and a high number of livestock per 100 ha of farm area. The forestry function was prevalent in rural areas situated in the forest complexes of Borecka Forest, Napiwodzko-Ramucka Forest, Augustów Primeval Forest, Białowieża Forest and Knyszyń Forest. A predominance of non-agricultural activities, including industrial, residential and service functions, was noted in 10% of rural municipalities in North-Eastern Poland, of which more than 60% are situated in the Region of Warmia and Mazury, mainly in its central part. The smallest group with a predominance of tourist and recreational functions covered only 9%

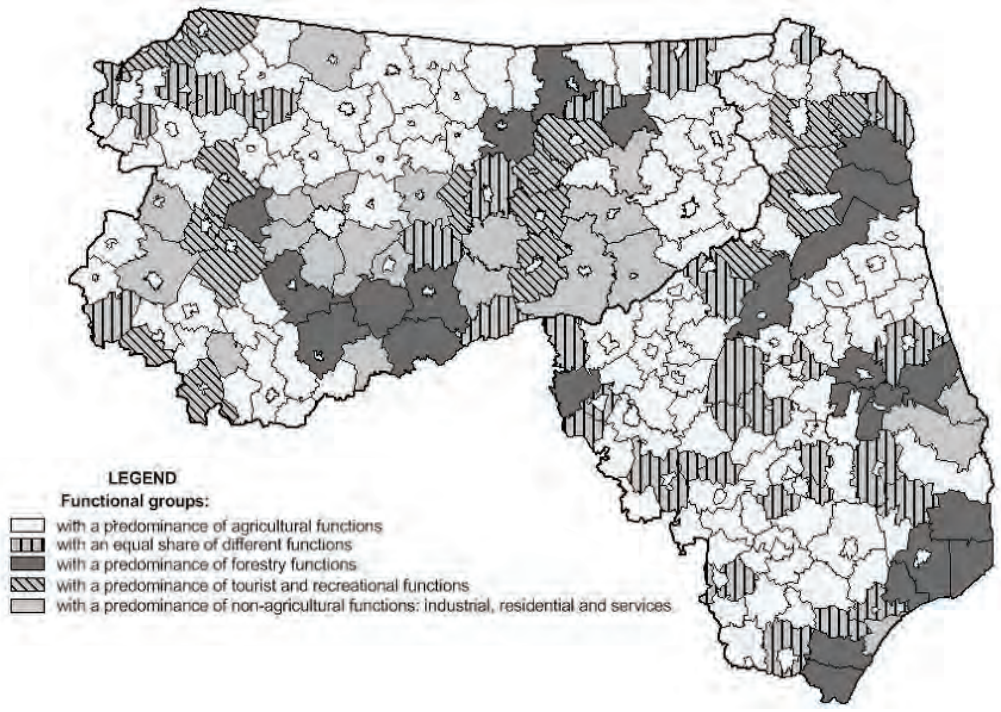

Figure 1. Functional classification of rural areas in North-North Eastern Poland in 1988.
Source: Stola W. (1993) Struktura przestrzenna i klasyfikacja funkcjonalna obszarów wiejskich Polski (Spatial structure and functional classification of rural Polish), Dokumentacja Geograficzna, IGiPZ PAN, 3, Warszawa, Polska.

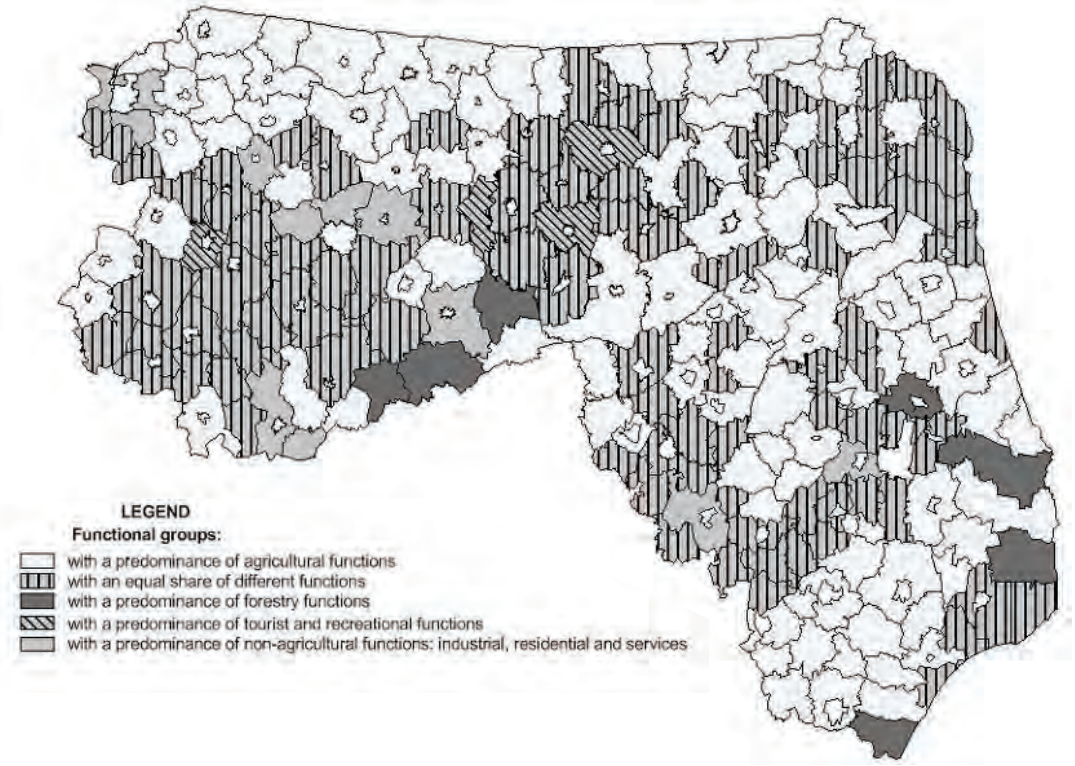

Figure 2. Functional classification of rural areas in North-Eastern Poland in 2012.
Source: Own elaboration.

of municipalities in the Masurian Lake District and the Suwałki-Augustów Lakeland. Different functions were distributed evenly in more than 17% of the analyzed municipalities.

The results of the classification conducted in 1988 and 2012 reveal changes in the functional structure of rural areas in North-Eastern Poland. The highest decrease in the number of municipalities was noted in groups with a predominance of forestry, tourist, recreational and non-agricultural functions. The smallest drop in the number of municipalities was reported in the group with a predominance of agricultural functions, although the significance of agricultural municipalities continues to be high (48%) relative to the remaining functional groups. The number of municipalities with an equal share of various functions increased more than twofold. The reported results are consistent with general trends, and they are indicative of progressive diversification of rural areas in North-Eastern Poland. Social and economic processes were the main drivers of diversity in the functional spatial structure of rural areas in 2012.

An analysis of the distribution of different functions in North-Eastern Poland reveals changes in the classification status of municipalities situated in the central part of the Region of Warmia and Mazury and in northern and western parts of the Region of Podlasie. The noted processes could contribute to growing levels of functional diversification in rural areas due to equal significance of two or more functional groups in a single municipality. The number of municipalities with predominantly agricultural functions decreased from 109 in 1988 to 100 in 2012, i.e. by only 9%. The above results testify to strong correlations between favorable farming conditions and the prevalence of agricultural functions. Agricultural development should be linked with food production and processing without generating negative consequences for the environment.

Conclusions

The functional spatial structure of rural areas in North-Eastern Poland and in all of Poland is characterized by growing diversification. Rural areas that were classified as monofunctional in the 1980s are increasingly often transformed into multifunctional areas where non-agricultural activities complement farming practices. In 1988 agriculture was the predominant function in North-Eastern Poland, including in the Region of Warmia and Mazury and the Region of Podlasie. Forestry, non-agricultural activities of equivalent type, tourist and recreational services played a less important role in the functional structure. A comparison of classification results for 1988 and 2012 reveals changes in the functional structure of rural areas in North-Eastern Poland. The number of municipalities with equal proportions of

various functions increased more than twofold. This observation is consistent with a more general trend, and it points to growing functional diversity of rural areas in North-Eastern Poland. The differences in the spatial and functional structure of rural areas in 2012 can be attributed to social and economic changes. Despite the above, farming practices continue to play an important role in the analyzed regions, in particular in areas characterized by the most supportive conditions for agricultural production. The agricultural function could significantly benefit from the development of organic farming and food processing. Non-farming activities associated with agricultural production could delineate new directions for growth in the evaluated regions. Protection of the natural and cultural landscape should always be an important consideration in the process of proposing new directions for the development of rural areas (Vos and Meekes, 1999).

The relevant measures contribute to changes in the functional structure of rural areas, and they have been included in the National Spatial Development Concept 2030. Special efforts should be made to ensure that multifunctional development does not eradicate the distinct features of rural areas that contribute to their unique character in Poland and the European Union.

References

1. Bański J. (1999) Obszary problemowe w rolnictwie Polski (Problem areas in Polish agriculture). Prace Geograficzne 172, IGiPZ PAN, Warszawa, Polska, s. 128. (in Polish).
2. Bański J., Stola W. (2002) Przemiany struktury przestrzennej i funkcjonalnej obszarów wiejskich w Polsce (Transformation of the spatial and functional structure of rural areas in Poland). Studia Obszarów Wiejskich vol. 3, Warszawa, Polska, s. 203. (in Polish).
3. Bański J. (2007) Typy obszarów funkcjonalnych w Polsce (Types of functional areas in Poland). Available at: http://www.igipz.pan.pl/tl_files/igipz/ZGWiRL/Projekty/Ekspertyza_typologia.pdf, 14 February 2014. (in Polish).
4. Bański J. (2003) Transforming the functional structure of Poland`s rural areas. In: Bański J., Owsiński J. (eds.), *Alternatives for European Rural Areas*, ERDN, 1, IERiGŻ, IGiPZ PAN, Warszawa, Polska, pp. 19 – 37.
5. Bera M. (2013) Atrakcyjność turystyczna gmin wiejskich o cennych walorach przyrodniczych województwa warmińsko-mazurskiego i podlaskiego (Tourist attractiveness of rural municipalities with natural amenity assets in the Region of Warmia and Mazury and the Region of Podlasie). *Journal of Agribusiness and Rural Development*, Zeszyt 2 (28), s. 5 – 12. (in Polish).
6. Churski P. (2002) Problem areas and support areas in Polish regional policy, In: Miszewska B., Furmankiewicz M. (eds.) Przekształcenia regionalnych struktur funkcjonalno-przestrzennych (Transformation of regional functional and spatial structures). Rozprawy Naukowe Instytutu Geografii i Rozwoju Regionalnego T. VI. Uniwersytet Wrocławski. Instytut Geograficzny. Zakład Geografii Społecznej i Ekonomicznej. Zakład Zagospodarowania Przestrzennego. Wrocław, Polska, pp. 75 – 99.
7. Falkowski J. (1993) Przekształcenia funkcjonalno-strukturalne i przestrzenne obszarów wiejskich Polski (Functional, structural and spatial transformations of rural areas in Poland). Wydawnictwo Uniwersytetu Mikołaja Kopernika, Toruń, Polska, s. 202. (in Polish).
8. Gwiaździńska M. (2004) Przemiany społeczno-gospodarcze obszarów wiejskich województwa warmińsko-mazurskiego (Socioeconomic transformation of rural areas in the Region of Warmia and Mazury). Rozprawy i Materiały Ośrodka Badań Naukowych im. Wojciecha Kętrzyńskiego w Olsztynie nr 221, Olsztyn, Polska, s. 194. (in Polish).
9. Gwiaździńska-Goraj M., Jezierska-Thole A. (2013) The functional development in Poland. *Journal of Settlements and Spatial Planning (JSSP)*, Vol. 4. No 1/2013, pp. 53 – 58.
10. Gwiaździńska-Goraj M., Goraj S. (2011) Przekształcenia funkcjonalne obszarów wiejskich województwa warmińsko-mazurskiego (Functional transformations of rural areas in the Region of Warmia and Mazury). In: Namyślak B. (eds) Przekształcenia regionalnych struktur funkcjonalno-przestrzennych (Transformation of regional functional and spatial structures) Rozprawy Naukowe Instytutu Geografii i Rozwoju Regionalnego T.XX Uniwersytet Wrocławski, Instytut Geograficzny. Zakład Geografii Społecznej i Ekonomicznej. Zakład Zagospodarowania Przestrzennego Wrocław, Polska, s. 235 – 241. (in Polish).
11. Gwiaździńska-Goraj M., Goraj S. (2013) The contribution of the natural environment to sustainable development on the example of rural areas in the Region of Warmia and Mazury. *Journal Rural Development*, Volume 6, Book, pp. 266 – 271.
12. Jongman R., Külvik M., Kristiansen I. (2004) European ecological networks and greenways, *Landscape and Urban Planning*, 68, pp. 305 – 319.

13. Koncepcja Przestrzennego Zagospodarowania Kraju 2030 (National Spatial Development Concept 2030). Available at: http://www.mir.gov.pl/rozwoj_regionalny/polityka_przestrzenna/kpzk/strony/koncepcja_przestrzennego_zagospodarowania_kraju.aspx, 14 February 2014. (in Polish).
14. Kluvankova-Oravska T. (2004) Structural funds the challenge for sustainable development and regional disparity in the Slovak Republic, *The European Journal of Social Science Research*, Volume 17, Issue 1, pp. 61 – 73.
15. Michalewska-Pawlak M. (2011) Rural areas development as a field of intervention of the European Union Cohesion Policy after 2013. *Studies in Agricultural Economics*, 113, pp. 161 – 166.
16. Roszkowska-Mądra B. (2005) Obszary zagrożeń społeczno-gospodarczych pogranicza wschodniej Polski (Areas of socioeconomic risks in the eastern borderlands of Poland). Optimum. Studia ekonomiczne NR 4 (28), Polska, s. 105 – 117. (in Polish).
17. Stanny M., Czarnecki A. (2010) Level and Determinants of Sustainable Rural Development in the Region of Green Lungs of Poland. In: Linking Competitiveness with Equity and Sustainability: New Ideas for the Socioeconomic Development of Rural Areas. (series: Rural areas and development – vol. 7), University of Debrecen, ERDN (European Rural Development Network), Warsaw, Poland, pp. 197 – 212.
18. Stola W. (1993) Struktura przestrzenna i klasyfikacja funkcjonalna obszarów wiejskich Polski (Spatial structure and functional classification of rural areas in Poland). Dokumentacja Geograficzna, IGiPZ PAN,3 Warszawa, Polska, s. 100. (in Polish).
19. Vos W., Meekes H. (1999) Trends in European cultural landscape development: perspectives for a sustainable future, *Landscape and Urban Planning*, 46, pp. 3 – 14.

PROBLEM RURAL AREAS IN THE REGION OF WARMIA AND MAZURY

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Abstract
Rural areas in Poland are vastly differentiated in their level of social and economic development. Adverse natural, social, economic and technological processes contribute to the formation of problem areas. Negative phenomena can spread across several municipalities, contributing to the number and severity of problems. Rural municipalities characterized by a low level of social and technical development are not attractive sites for prospective investors or home buyers. Geographical location can also contribute to the formation of problem areas. The Region of Warmia and Mazury borders the Kaliningrad Region, and it is one of the least developed areas in Poland. Rural areas in Warmia and Mazury are characterized by significant disparities in the level of social and economic development. The aim of this paper was to identify problem rural areas in the Region of Warmia and Mazury based on indicators of social, demographic, economic and infrastructure development. Problem areas in the Region of Warmia and Mazury were identified using Hellwig's taxonomic measure of development. The results of our analysis indicate that in rural areas in the Region of Warmia and Mazury, the most severe problems are observed in typically agricultural municipalities which have a peripheral location and where state-owned farms had acted as the main employer.
Key words: rural areas, problem areas, Region of Warmia and Mazury.

Introduction

Rural areas in Poland are vastly differentiated in their level of social and economic development due to endogenous and exogenous factors which affect a given region. The gap between the most developed areas and those that lag behind continues to grow, and it contributes to the formation of problem areas which are characterized by adverse environmental processes and developmental trends. Negative phenomena can spread across several municipalities, contributing to the number and severity of problems. Rural municipalities characterized by a low level of social and technical development are not attractive sites for prospective investors or home buyers. Geographical location can also contribute to the formation of problem areas. In line with the classical core-periphery model, suburban areas are characterized by much higher levels of development than areas situated in peripheral districts of a region or country (Wójcik, 2012; Pénes, 2013; Stanny, 2013). The Region of Warmia and Mazury borders the Kaliningrad Region, and it is one of the least developed areas in Poland. Rural areas in Warmia and Mazury are characterized by significant disparities in the their level of social and economic development. This paper relies on Hellwig's taxonomic measure of development to identify rural areas in the Region of Warmia and Mazury which face demographic, social, economic and infrastructure problems. According to J. Bański (1999), problem areas and the underlying causes of developmental gaps should be identified to minimize those negative phenomena.

Materials and Methods

Demographic, social, economic and infrastructure problems in rural areas in the Region of Warmia and Mazury

The Region of Warmia and Mazury has the lowest population density in Poland which is estimated at 25 persons km^{-2} on average. Rural municipalities with the lowest population density (below 19 persons km^{-2}) are situated mainly in the northern and eastern parts of the region. The highest population density (above 30 persons km^{-2}) is reported in municipalities that directly neighbor the cities of Olsztyn and Elbląg and in the north-western parts of the region in the proximity of national roads No. 7 and 16. Demographic trends are also very important determinants of population growth. In rural areas of the Region of Warmia and Mazury, population growth in 2011 ranged from -4.8‰ (municipality of Stare Juchy) to 9.3‰ (municipality of Stawiguda). Spatial variations in demography indicate that population growth below 2‰ was noted predominantly in rural municipalities situated in northern and eastern parts of the region. Municipalities occupying central and western sections of the region were generally characterized by population growth higher than 5‰. Migration patterns strongly affect the local population, its structure and spatial distribution. The Region of Warmia and Mazury has been long characterized by a population outflow due to low levels of urban growth, lagging infrastructure development and high unemployment since the political transformations of 1989 (Frenkel, 2002; Stanny, 2013). The opening of selected EU labor markets to Polish citizens also contributed to migration, although the migration rate decreased after 2008 when Europe experienced an economic downturn. In rural municipalities of the region, the average migration rate reached -1.8‰ in 2011. The highest migration rates (above 10 ‰) were noted in municipalities neighboring Olsztyn, and the lowest (above -7.0‰) – in municipalities situated in

the eastern part of the region. The changes in rural population resulting from increased migration and lower population growth contribute to population aging. In rural areas of the Region of Warmia and Mazury, the proportions of different age groups were as follows: young people – 23%, people of working age – 64%, retired – 13%. The most adverse trends were reported in rural municipalities in northern and eastern parts of the region which had the highest share of older citizens and the lowest percentage of young people. The above correlations are indicative of progressing aging of society. Unemployment poses a significant problem in the Region of Warmia and Mazury (Gajowiak, 2013). In 2011, registered unemployment reached 20.1%, and it was the highest in the country (the national average is 12.5%). Unemployment was particularly high in municipalities whose residents had been previously employed in state-owned farms. In rural areas of Warmia and Mazury, more than 15% of working-age people are registered as unemployed.

High levels of enterprise significantly contribute to economic development. In 2011, 31,720 businesses were registered in the REGON (Register of the National Economy) system in rural areas, accounting for 27.0% of the total number of enterprises in Warmia and Mazury. Enterprise concentrations are illustrated by the number of business registrations per 10,000 inhabitants which reached 537 in rural areas in 2011. The highest values of this indicator were noted in rural municipalities situated in the direct proximity of Olsztyn and Elbląg and in the central part of the region. In 2011, those municipalities also reported the highest number of newly registered businesses per 10,000 inhabitants. The lowest number of enterprises and newly registered businesses per 10,000 residents was noted in northern municipalities where employment had previously concentrated in state-owned farms. In those areas, the growth of enterprise is inhibited mainly by low levels of education of the local labor force, lagging infrastructure development, lack of capital and an unsupportive business environment (Gwiaździńska-Goraj, 2011). In rural municipalities of Warmia and Mazury, businesses that employ up to 9 people account for 94.3% of local firms, whereas entities with more than 250 employees constitute the smallest group (0.05%) of businesses.

Infrastructure is an important factor that stimulates enterprise growth. The level of infrastructure development determines the quality of life and the region's attractiveness for prospective investors. Water supply is a critical infrastructure element, and in 2010, the average coverage of water supply networks in rural municipalities in Warmia and Mazury was determined at 50.0 km (100 km^2)$^{-1}$, ranging from 5.8 km (100 km^2)$^{-1}$ in the municipality of Orzysz to 155 km (100 km^2)$^{-1}$ in the municipality of Kurzętnik. The noted variations can be attributed to dispersed settlement as well as the presence of extensive forests and lakes in the region. Vast disproportions are also observed in the coverage of sewerage networks in rural areas. Sewers are more expensive to build than water supply pipelines, and some municipalities lack the required funding. The highest sewer coverage in excess of 55 km (100 km^2)$^{-1}$ was reported in municipalities adjacent to Olsztyn (Gietrzwałd and Stawiguda), and the lowest – in municipalities situated in northern and western parts of the region.

Social infrastructure is yet another element that considerably influences social and economic development in rural areas. The majority of schools in rural municipalities are primary and middle schools, and the opportunities for secondary education are significantly limited (Gwiaździńska-Goraj, 2011). In 2010, there were a total of 379 primary schools and 132 middle schools in rural municipalities of Warmia and Mazury, with an average of 87.2 students per primary school and 120.2 students per middle school. Computer access in schools can help expand young people's knowledge. In rural areas, there were an average of 7 primary school students (excluding special schools) and 9 middle school students (excluding special schools) per computer with Internet access. The above statistics are below the regional average. Libraries (around 200), community centers and clubs (around 90) also play an important role in the social change process. The quality of health care services in rural areas is visibly lower in comparison with urban centers. In 2011, rural municipalities operated 153 health care facilities which accounted for only 19% of the total number of health care centers in Warmia and Mazury. Many rural municipalities lack the funds to upgrade health care facilities and provide them with expensive equipment.

Methods

Problem areas have different definitions in literature. According to S. Ciok (1996), a problem area is a territory characterized by low efficiency of social, economic and spatial structures. R. Domański (1987) identifies problem areas as those parts of a region which are affected by particularly severe problems or problems that are difficult to solve. According to J. Bański (1999), a problem area is a spatial unit characterized by abnormality in one or more elements of space. All of the cited authors agree that adverse phenomena in certain areas of activity thwart social and economic development. The Region of Warmia and Mazury is characterized by a low level of social and economic development, high unemployment, low levels of enterprise and low levels of technical and social infrastructure. Those problems contribute to Warmia and Mazury's status of a problem area on

the national scale. The present problems are largely rooted in the region's history and the post-war efforts to promote industrial development mainly in western regions of Poland. Before the political transformations of 1989, Warmia and Mazury was a largely agricultural region due to supporting natural conditions and a high share of state-owned land. The introduction of a free market economy further deepened social and economic inequalities between Polish regions. In Warmia and Mazury, the transformation process was particularly problematic on account of the prevalence of farmland that was owned by the socialist authorities. Structural unemployment, weakly developed technological and social infrastructure and deteriorating living standards contributed to the social divide among rural municipalities and the formation of areas experiencing particular problems in social, economic and infrastructural development. According to J. Bański, problem areas have many features in common, and areas of interference often have to face multiple challenges. In this study, problem rural areas in Warmia and Mazury were identified based on indicators of social, demographic, economic and infrastructure development.

Social and demographic indicators: population density, population growth per 1000 inhabitants, migration rate per 1000 inhabitants, share of working-age persons in total population, share of unemployed persons in the working-age population.

Economic indicators: number of businesses per 10,000 inhabitants, share of industrial and construction sector businesses in the total number of businesses, share of service providers in the total number of businesses, share of newly registered businesses in the total number of businesses, income per capita.

Indicators of technical and social infrastructure development: water supply coverage per 100 km^2, sewerage coverage per 100 km^2, percentage share of households with a bathroom in the total number of households, average usable floor area per person, number of students per computer with Internet access in primary schools (excluding special schools), number of library books per 1000 inhabitants, number of inhabitants per health care facility.

Problem areas in the Region of Warmia and Mazury were identified based on Hellwig's taxonomic measure of development (Feltynowski and Nowakowska, 2009). The analyzed municipalities were classified into groups with the use of the following formula:

$$d_i = \frac{C_{ij}}{C_o} \quad (1)$$

where:
d_i - measure development
C_{ij} – distance between point X_{ik} and X_{jk}
C_o - model

The distance between point X_{ik} and X_{jk} is calculated with the below formula:

$$C_{ij} = \sum_{k=1}^{m} \left[(X_{ik} - X_{jk})^2 \right]^{\frac{1}{2}} \quad i= 1,2,...n \quad (2)$$

$$C_o = \overline{C}_{ij} + 2S_o \quad (3)$$

$$\overline{C}_{ij} = \frac{1}{n} \sum_{i=1}^{n} C_{ij} \quad (4)$$

$$S_o = \left[\frac{1}{n} \sum_{i=1}^{n} (c_{ij} - \overline{c}_j)^2 \right]^{\frac{1}{2}} \quad (5)$$

where:
X_{ik} - standardized variable
X_{jk}- stimulant or destimulant for a given indicator
S_o - standard deviation of distance from model

Classes are identified on an interval scale of development indicators based on the arithmetic mean and standard deviation. The following principles were applied to identify six classes by use arithmetic average and standard deviation

Results and Discussion

Based on the analyzed indicators, the analyzed municipalities were grouped into one of the six classes, ranging from class I characterized by the highest level of social and economic development to class VI marked by the lowest level of development. In the group of 100 analyzed municipalities, 4 were identified as belonging to class I, 9 – class II, 30 – class III, 43 – class IV, 14 – class V, and none were assigned to class VI, which is a positive symptom. Class V municipalities which are possible candidates for class VI were regarded as problem areas.

The spatial distribution of rural municipalities which lag behind in social, economic and infrastructure development indicates that the encountered problems are correlated with local conditions, the extent and rate of socio-economic changes. Municipalities characterized by high scenic beauty (Masurian Lakeland) have achieved a higher level of social and economic growth than areas characterized by a predominance of state-owned farms in the past where high unemployment is closely correlated with a low level of social and economic development. The most problematic municipalities are situated in the northern part of the region. Their demographic situation is unsatisfactory, and they scored below the average in most population metrics. Adverse demographic trends and high unemployment significantly detract from those municipalities' attractiveness for investors. The average number of businesses per 10,000 inhabitants

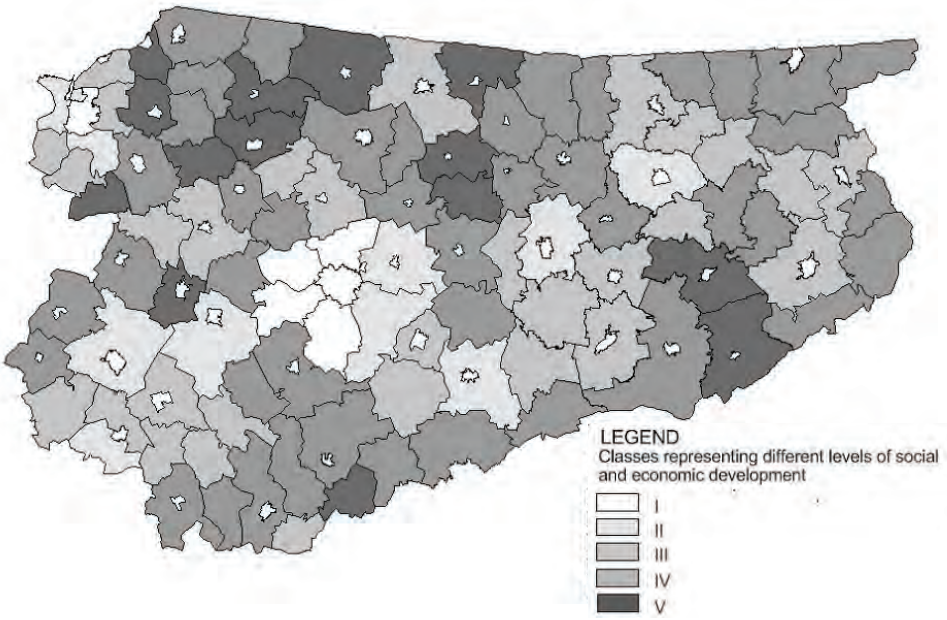

Figure 1. Level of social and economic development in rural municipalities of the Region of Warmia and Mazury in 2011.

Source: own study

was not exceeded in any of the municipalities assigned to this class. The development of non-farming activities, which could improve the situation of the least developed municipalities, was also limited due to low levels of education and dilapidated technical infrastructure. Four out of 14 municipalities in class V failed to attain the average values of six indicators of technical and social infrastructure development (regional average for rural municipalities). Geographic location is also a robust determinant of local development. The majority of problem municipalities are situated along the Polish border which is also the EU's eastern frontier.

A total of 14 rural municipalities were classified as problem areas based on the results of the analysis. The problems experienced by the municipalities of Bisztynek, Godkowo, Rychliki, Orneta, Kolno, Frombork, Pieniężno and Sępopol resulted from several overlapping negative trends in social, economic and infrastructure development. The most common causes of lagging development in Warmia and Mazury include the former predominance of state-owned farms, low levels of involvement in non-farming activities (low level of functional diversification) and peripheral location. The correlations between the analyzed municipalities' classification status and adverse developmental trends were examined.

Until the end of the 1980s, rural municipalities in the Region of Warmia and Mazury had the status of agricultural areas (Gwiaździńska-Goraj and Jezierska-Thole, 2013; Gwiaździńska-Goraj and Goraj, 2013). Political transformations initiated far-reaching social and economic changes whose pace and character differed subject to local conditions (Kluvankova-Oravska, 2004). Those transitions further widened the developmental gap among rural municipalities in the region. Municipalities with a high share of state-owned farms, including class V municipalities, were most reluctant to adapt to the requirements of a free market economy. The share of state-owned farms in the area of 14 problem municipalities in 1988 ranged from 13% in Janowiec Kościelny to 50.3% in Rychliki. State-owned farms were particularly difficult to restructure, and their closure led to significant unemployment (Gajowiak, 2013). Many farm employees were low-skilled workers with very few chances of employment in other sectors of the economy. Those municipalities were not attractive sites for prospective investors or home buyers. Low levels of education and lagging infrastructure development posed significant barriers to enterprise growth.

Low levels of enterprise can contribute to the formation of problem areas. Non-farming activities create new jobs, generate additional income for members of the local community and promote social and economic grown in rural areas (Pałka, 2010). According to J. Bański and W. Stola (2002), rural areas with a higher level of social and economic development are characterized by greater functional complexity, and the above observation was validated by the results of our study. The majority of rural municipalities identified as problem areas were monofunctional territorial units with predominantly agricultural economies (Fig. 3).

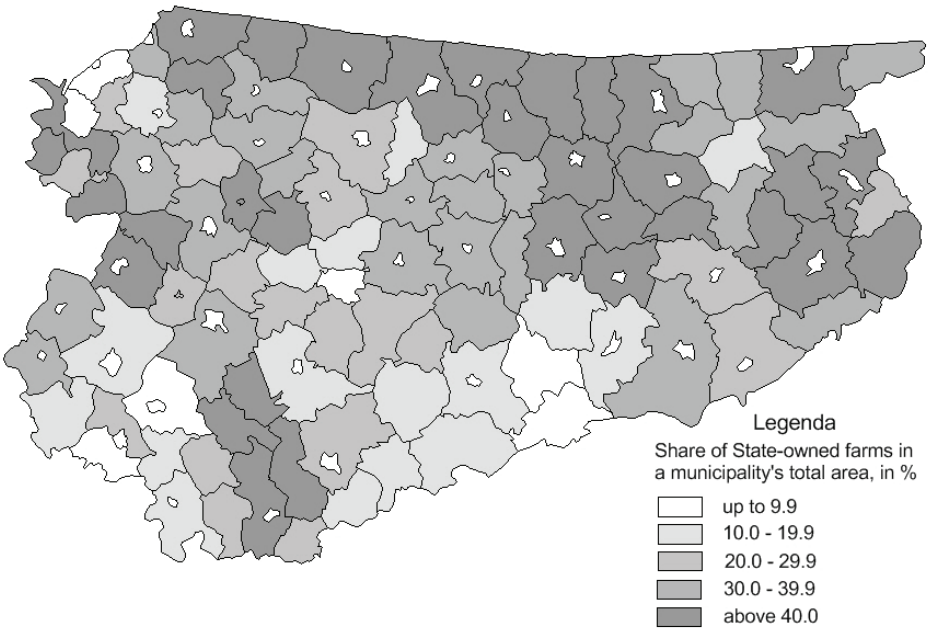

Figure 2. State-owned farms in the Region of Warmia and Mazury in 1988.

Source: Gwiaździńska M. (2004) *Przemiany społeczno-gospodarcze obszarów wiejskich województwa warmińsko-mazurskiego (Socio-economic transformation of rural areas of the Warmia and Mazury).* Rozprawy i Materiały Ośrodka Badań Naukowych im. Wojciecha Kętrzyńskiego w Olsztynie nr 221, Olsztyn, Polska, s. 194. (in Polish).

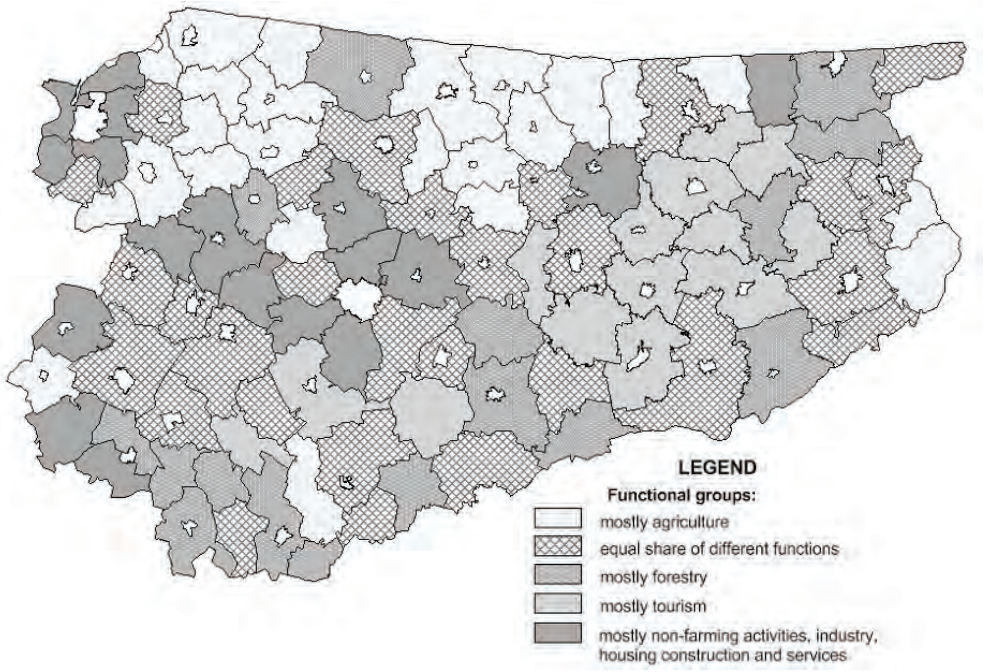

Figure 3. Functional classification of rural areas in the Region of Warmia and Mazury in 2009.

Source: Gwiaździńska-Goraj M., Goraj S. (2011) Przekształcenia funkcjonalne obszarów wiejskich województwa warmińsko-mazurskiego (Functional transformations of rural areas of the Warmia and Mazury). In: Namyślak B. (eds) Przekształcenia regionalnych struktur funkcjonalno-przestrzennych (The transformation of region al structures of functional and spatial). Rozprawy Naukowe Instytutu Geografii i Rozwoju Regionalnego T.XX Uniwersytet Wrocławski, Instytut Geograficzny. Zakład Geografii Społecznej i Ekonomicznej. Zakład Zagospodarowania Przestrzennego Wrocław, Polska, s. 235 – 241. (in Polish).

Geographic location can also contribute to developmental lags, and peripheral municipalities which are situated remotely from economic hubs are very often identified as problem areas (Jezierska-Thole and Gwiazdzinska-Goraj, 2013). Ten out of the 14 problem areas identified in this study are situated in the northern part of Warmia and Mazury which borders the Kaliningrad Oblast. Poland's accession to the European Union and its inclusion in the Schengen area led to the further marginalization of areas located on both sides of the EU's new eastern frontier (Kawałko, 2006; Bański, 2010; Gwiaździńska-Goraj, 2011). Proximity to the border could have significantly contributed to the formation of problem areas in the analyzed region.

The results of our analysis indicate that the developmental gap among problem areas and the remaining municipalities in the Region of Warmia and Mazury could be attributed to several factors. In 10 out of the 14 identified problem municipalities, state-owned farms occupied more than 30% of the local territory. The analyzed areas were also characterized by low levels of non-farming activities. Eight out of 14 problem areas were monofunctional units with largely agricultural economies. In the group of 14 municipalities, 10 have a peripheral location along the border between Poland and the Kaliningrad Oblast. Adverse trends in social, economic and infrastructure development can spread across several municipalities, contributing to the number and severity of problems (Jezierska-Thole and Gwiazdzinska-Goraj, 2013). The identified problem areas should be included in special programs aiming to create a favorable environment for social and economic growth.

Conclusions

Problem areas are characterized by low levels of social and economic development and adverse consequences of post-socialist transformations, including high unemployment. In the Region of Warmia and Mazury, the most severe problems are observed in typically agricultural municipalities which have a peripheral location and where state-owned farms had acted as the main employer. In comparison with other municipalities in Warmia and Mazury, those areas are characterized by demographic collapse, high unemployment, low level of technical and social infrastructure development and low level of involvement in non-farming activities. The majority of problem areas are situated in the northern part of the region. The absence of measures aiming to eliminate the barriers to development can further marginalize those areas and deepen the observed social, economic and infrastructure inequalities.

References

1. Bański J. (1999) *Obszary problemowe w rolnictwie Polski (Problem areas in Polish agriculture).* Prace Geograficzne 172, IGiPZ PAN, Warszawa, Polska, s. 128. (in Polish).
2. Bański J., Stola W. (2002) *Przemiany struktury przestrzennej i funkcjonalnej obszarów wiejskich w Polsce (Transformation of the spatial structure and functional rural areas in Poland).* Studia Obszarów Wiejskich tom 3, Warszawa, Polska, s. 203. (in Polish).
3. Bański J. (2010) Granica w badaniach geograficznych – definicja i próby klasyfikacji (The limit in geographical research - definition and attempts to classify). Przegląd Geograficzny, 82, 4, IGiPZ PAN, Warszawa, Polska s. 489 – 508. (in Polish).
4. Ciok. S. (1996) Teoretyczne i empiryczne koncepcje obszarów problemowych (Theoretical and empirical concepts of problem areas). Acta Univ. Wratisl., 1796, Prace Inst. Geogr., Seria B, 13, Uniw. Wrocławski, Wrocław, Polska, s. 5 – 26. (in Polish).
5. Domański R. (1987) Przestrzenna organizacja rozwoju regionalnego (Spatial organization of regional development). Studia KPZK PAN, 93, Warszawa, Polska, s. 159. (in Polish).
6. Feltynowski M., Nowakowska A. (2009) Metoda oceny potencjału innowacyjnego regionów (Method for assessing the innovation potential of regions). In: Nowakowska A. (eds) Zdolności innowacyjne polskich regionów (Innovative capacity of Polish regions), Wydawnictwo Uniwerstytetu Łódzkiego, Łódz, Polska, s. 11 – 26. (in Polish).
7. Frenkel I. (2002) Wiejskie obszary problemowe w aspekcie sytuacji demograficznej (Rural areas of concern in terms of the demographic situation). In: A. Rosner (eds) Wiejskie obszary kumulacji barier rozwojowych (Rural areas of accumulation of barriers to development). Polska Akademia Nauk, Instytut Rozwoju Wsi i Rolnictwa, Warszawa, Polska, s. 29 – 50. (in Polish).
8. Gajowiak M. (2013) Deficyt kapitału społecznego na popegerowskich obszarach jako bariera zrównoważonego rozwoju polskiej wsi (Lack of social capital on post-state-owned farms as a barier ofsustainable development of polish villiges). Folia Pomer. Univ. Technol. Stetin. 2013, Oeconomica 299 (70), s. 71 – 80. (in Polish).
9. Gwiaździńska M. (2004) *Przemiany społeczno-gospodarcze obszarów wiejskich województwa warmińsko-mazurskiego (Socio-economic transformation of rural areas of the Warmia and Mazury).* Rozprawy i

Materiały Ośrodka Badań Naukowych im. Wojciecha Kętrzyńskiego w Olsztynie nr 221, Olsztyn, Polska, s. 194. (in Polish).
10. Gwiaździńska-Goraj M. (2011) Przemiany cech demograficznych ludności w latach 1988 – 2009 i ich wpływ na peryferyzację obszarów wiejskich województwa warmińsko-mazurskiego (Transformation of the population demographics in the years 1988 – 2009 and their impact on peripheral rural areas in the Warmińsko-Mazurskie Voivodship). In: M. Wesołowska (eds) Wiejskie obszary peryferyjne - uwarunkowania i czynniki aktywizacji (Peripheral rural areas-conditions and factors stimulating to activity). Studia Obszarów Wiejskich, tom 26, Warszawa, Polska, s. 153 – 174. (in Polish).
11. Gwiaździńska-Goraj M. (2011) Rozwój społeczno-gospodarczy obszarów wiejskich w strefie przygranicznej województwa warmińsko-mazurskiego (Socio-economic development of rural areas in the border area of Warmia and Mazury). Acta Scientarum Polonorum Administratio Locorum 10 (3) 2011, Wydawnictwo Uniwersytetu Warmińsko-Mazurskiego, Olsztyn, Polska, s. 73 – 78. (in Polish).
12. Gwiaździńska-Goraj M., Goraj S. (2011) Przekształcenia funkcjonalne obszarów wiejskich województwa warmińsko-mazurskiego (Functional transformations of rural areas of the Warmia and Mazury). In: Namyślak B. (eds) Przekształcenia regionalnych struktur funkcjonalno-przestrzennych (The transformation of region al structures of functional and spatial). Rozprawy Naukowe Instytutu Geografii i Rozwoju Regionalnego T.XX Uniwersytet Wrocławski, Instytut Geograficzny. Zakład Geografii Społecznej i Ekonomicznej. Zakład Zagospodarowania Przestrzennego Wrocław, Polska, s. 235 – 241.(in Polish).
13. Gwiaździńska-Goraj M., Goraj S. (2013) The contribution of the natural environment to sustainable development on the example of rural areas in the Region of Warmia and Mazury. *Journal Rural Development*, Volume 6, Book 3, pp. 266 – 271.
14. Gwiaździńska-Goraj M., Jezierska-Thole A. (2013) The functional development in Poland. *Journal of Settlements and Spatial Planning (JSSP)*, Vol. 4. No 1/2013, pp. 53 – 58.
15. Jezierska-Thole A., Gwiazdzinska-Goraj M. (2013) Assessment of the Level of Economic Development of Rural Areas of Northern Poland *Journal Rural Development*, Volume 6, Book 1, pp. 548 – 552.
16. Kawałko B. Granica wschodnia jako czynnik ożywienia i rozwoju społeczno-ekonomicznego regionów przygranicznych. Synteza. (The eastern boundary as a factor in recovery and socio-economic development of border regions. Synthesis). Available at: https://www.mir.gov.pl/rozwoj_regionalny/poziom_regionalny/strategia_rozwoju_polski_wschodniej_do_2020/dokumenty, 23 January 2014. (in Polish).
17. Kluvankova-Oravska T. (2004) Structural funds the challenge for sustainable development and regional disparity in the Slovak Republic, *The European Journal of Social Science Research*, Volume 17, Issue 1, pp. 61 – 73.
18. Pałka E. (2010) Kierunki rozwoju pozarolniczej działalności na obszarach wiejskich w Polsce (The directions of development of non-agricultural economic activities in rural areas in Poland). Infrastruktura i ekologia obszarów wiejskich Nr 1/2010, PAN, Polska. s. 163 – 174. (in Polish).
19. Pénes J. (2013) The dimensions of peripheral areas and their restructuring in Central Europe, Hungarian Geographical Bulletin 62 (4), pp. 373 – 386.
20. Stanny M. (2013) *Przestrzenne zróżnicowanie rozwoju obszarów wiejskich w Polsce (Spatial diversification of rural area development in Poland).* Instytut Rozwoju Wsi i Rolnictwa Polskiej Akademii Nauk, Warszawa, Polska, s. 331. (in Polish).
21. Wójcik M. (2012) *Geografia wsi w Polsce. Studium zmiany podstaw teoretyczno-metodologicznych (Geography village in Poland. Study changes in a theoretical and methodological).* Wydawnictwo Uniwersytetu Łódzkiego, Łódź, Polska, s. 273. (in Polish).

FROUDE NUMBER FOR ESTIMATION OF BIODIVERSITY IN SMALL LITHUANIAN RIVERS

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Abstract
The majority of natural Lithuanian rivers were regulated during intensive land reclamation period. Straightening of rivers caused unfavourable conditions for biodiversity. Four tributaries of the Merkys river in the South Lithuania were selected to explore changes in biodiversity patterns and determine the relationships between flow energy distribution in beds and ecological status of selected rivers. The research has shown that variation of cross sections area was usually 1.2 to 2.3 times higher in natural beds as compared to regulated ones. The range of rivers flow energy, estimated by Froude number, values were characterized as higher in natural (0.0 to 0.35) streams than in regulated (0.0 to 0.20) ones. This is the reason why the biggest number of macroinvertebrate taxa during the research period was recorded in natural riverbeds and the lowest - in the fields of the regulated segments. The assessing the abundance of fish revealed that total fish density in natural river sections was four times higher than in regulated ones. The research has approved the importance of naturalness for biodiversity and rehabilitation of regulated rivers in Lithuania.
Key words: biodiversity, ecosystem, flow energy distribution, macrozoobenthos.

Introduction

The regulated rivers and streams currently make 82.6%, while natural - 17.4% of the overall network of small rivers in Lithuania (Gailiusis et al., 2001). By regulating the streams, it was mostly sought to adapt them to land drainage purposes and the cross-section of the river bed as well as the morphology is always modified. It affects shape and boundaries of the bed, slope structure, shoreline, bottom substrate and the overall hydraulic conditions of the flow in the river. Due to these modifications, the regulation of the rivers was named as one of the greatest threats to wildlife biodiversity and ecosystems (Rosenberg et al., 2000; Nakamura and Yamada, 2005; Horsák et al., 2009).

There are many publications indicating that both habitat structure and diversity have a very significant impact not only on the composition of fish species (Huet, 1959; Gorman et al., 1978, Angermeier et al., 1989; Rahel et al., 1991), but also on the trophic composition, i.e., determine the prevailing environmental groups not only by the habitat, spawning substrate, but also by the nutrition (Schlosser, 1982; Angermeier et al., 1983; Oberdorff et al., 1993). Natural change of rapids and slacks in the riverbed provides appropriate specific living conditions not only for fish, but also for invertebrates that are the primary food for most fish species.

In Lithuania reconstruction of regulated streams remains unsolved, but in the course of natural processes of self-naturalization the bed (bed form) and the flow with sediments interact and constitute a self-regulating system. Due to the effect of flow, changes occur in the shape of riverbed, while changes in the riverbed shape affect flow energy distribution in the transversal and longitudinal stream profiles.

Vaikasas and other authors (Vaikasas et al., 2011; Kemp et al., 2000) refer to Froude number as one of the most accurately calculated hydraulic criteria for complex evaluation of the impact of currents inertia forces on the geomorphological and ecological environment of river. They maintain that Froude number characterizes flow and sediment transport conditions in the cross-section of river (Althaus et al., 2008; Campisano et al., 2008; Gonzalez et al., 2008) very well.

Analysis of literature has shown that these regularities data of hydromorphometric parameters and energy flow distribution patterns of regulated streams are scarce. On the basis of our results of experimental research it was decided to estimate the impact of flow energy distribution in the bed of natural and regulated streams on their ecological status.

The aim of this study was to investigate interaction regularities of water flow energy distribution and stream beds during the naturalization process, to identify morphometric changes in the beds of streams and to assess the impact of these factors on the ecological status of rivers.

Materials and Methods

Study objects and methods

Four medium-size rivers of the Merkys basin in South East of Lithuania were selected for experimental research: Amarnia, Cirvija, Grūda, Spengla (Figure 1).

Amarnia is the right tributary of the Merkys that flows out from the lake Nedzingis. The length of the river is 15.1 km, the catchment area extends to 144 km^2. It is regulated from the springhead up to 10 km (Gailiušis et al., 2001). *Cirvija* is the right tributary of the Merkys. The length of the river is 14.6 km, the catchment area comprises 81.2 km^2. The whole riverbed is regulated. *Grūda* is the left tributary of the Merkys, originates on the Lithuanian-Belarusian border, in the lake Grūda located in Belarusian forest.

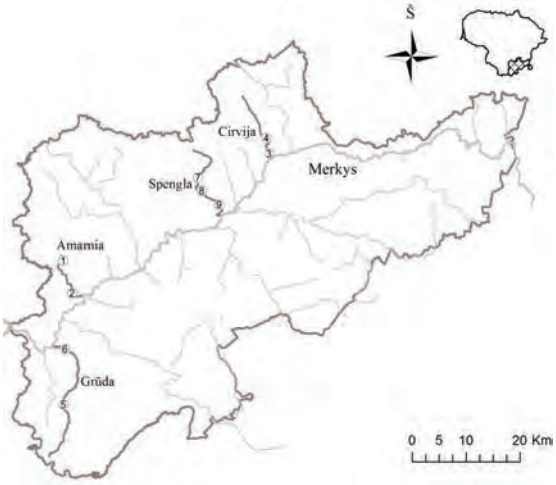


Figure 1. The scheme of selected rivers and research sites in the Merkys river basin.

The length of the river is 36.2 km, the catchment area - 248.4 km^2. The length distance of 22.2 km from the springhead is regulated. *Spengla* is the right tributary of the Merkys. The length of the river is 25.9 km, the catchment area – 148.3 km^2. Spengla originates in Gruodis lake. The middle part of Spengla is regulated (from 19.6 to 13 km) (Gailiušis et al., 2001). The main characteristics of researched rivers are presented in Table 1.

Research of the physical characteristics of riverbeds

In the studied sections of river measurements of discharges, bed depth and flow velocity were conducted using an acoustic „StreamPro ADCP“

Table 1

General characteristics of the researched river stretches

No.	River, stretch	River bed (N - natural) (R – regulated)	River type	Catchment area, km^2	Aver. river width, m	Aver. river depth, m	Average discharge m^3 s^{-1}	River bed gradient, m/km	Prevailing riverbed ground	Length of the studied stretch, m
1	Amarnia RL	R	1	60	7.5	0.47	0.51	1.12	silt, sand	235
2	Amarnia NM	N	3	143	7.3	0.35	1.02	3.95	sand, gravel, rocks	84
3	Cirvija RL	R	1	53	6.9	0.37	0.40	1.58	sand	129
4	Cirvija RM	R,	1	67	7.9	0.24	0.36	1.62	sand, gravel, rocks	70
5	Grūda RL	R	3	165	7.8	0.65	0.73	0.74	sand	180
6	Grūda NM	N	3	236	9.7	0.46	1.52	2.45	sand, gravel, rocks	143
7	Spengla RL	R	1	58	8.4	0.49	0.47	0.71	silt, sand	308
8	Spengla RM	R	3	107	10.5	0.59	0.93	0.73	silt, sand	170
9	Spengla NM	N	3	116	9.0	0.36	1.14	2.61	sand, gravel, rocks	138

device. To determine „StreamPro ADCP“ position in space (x, y coordinates) in open riverbeds, the GPS „GeoXH“ receiver was used. In cases when woody vegetation used to cover riverbeds and the use of GPS due to major errors was impossible, geodimeter was applied to ascertain the position of the device, the data of which were coordinated by GPS device. Riverbed shoreline was measured by GPS or geodimeter. The obtained riverbed points along with flow velocity and depth values with the aid of ArcGIS 10.1 programs were interpolated by geostatistical methods and the surfaces (grids) of riverbed depths as well as flow velocities were obtained (size 0.2x0.2 m). Having these surfaces, the dimensionless Froude number, characterizing a kinetic and potential energy ratio of river flow in each cell of the studied segments, was calculated using the formula:

$$Fr = \frac{v}{(gh)^{1/2}} \quad (1)$$

where: v – flow velocity, (m s^{-1}); g – acceleration of gravity, (m s^{-2}); h – riverbed depth, m.

Research of macrozoobenthos and ichtiofauna

Macrozoobenthos samples were collected using standard hydrobiological net, with the hole size of 25x25 cm, network porosity - 0.5 mm. Macroinvertebrates were captured in two ways – by a “kick” method, catching in four 0.1 m^{-2} area (0.40x0.25 m) (Arbačiauskas, 2009) bottom surfaces of the selected ground type (microhabitat), and catching with a net within 10 minutes in each survey site of all possible biotopes, where benthic invertebrates can live, distributing research efforts so that the total sample would represent mean distribution of the study site habitats. Capturing by the first method, the net is placed on a substrate with the opening against the stream, while bottom surface substrate of the directly opposite area is turned by hand (if deep, by feet) for 1 min. Drifted by current into the net, macroinvertebrates together with soil impurities are rinsed several times. The collected, unsorted in the field material is placed in plastic containers and transported to the laboratory. During the study period, 135 samples of macrozoobenthos were compiled and analyzed. Research sites were evaluated according to the following biotic characteristics: total number of macrozoobenthos taxa, number of pollution-sensitive EPT (*Ephemeroptera*, *Plecoptera*, *Trichoptera*) (mayflies, stoneflies, caddisflies taxa, total abundance of macrozoobenthos (ind.m^{-2}), the total and relative (%) abundance of mayflies, stoneflies, caddisflies, EPT taxa chironomids, oligochaetes (*Oligocheta*), beetle larvae (*Coleoptera*). The study areas were also assessed by relative abundance (%) of functional dietary groups of macroinvertebrates: collectors, scrapers, shredders, filtrators, predators. The status of macrozoobenthos communities was assessed by two indices: the Danish Stream Fauna Index (DSFI) (Arbačiauskas, 2009), which assesses the state of communities by qualitative taxonomic composition, and the HBI index (Hilsenhoff, 1988), which includes quantitative indicators for each taxon. Hilsenhoff Biotic Index (HBI) (Hilsenhoff, 1988) is calculated by the following formula:

$$HBI = \frac{\sum x_i t_i}{n} \quad (2)$$

where: x_i – number of individuals in a family, t_i - family tolerance value, n total number of individuals per sample.

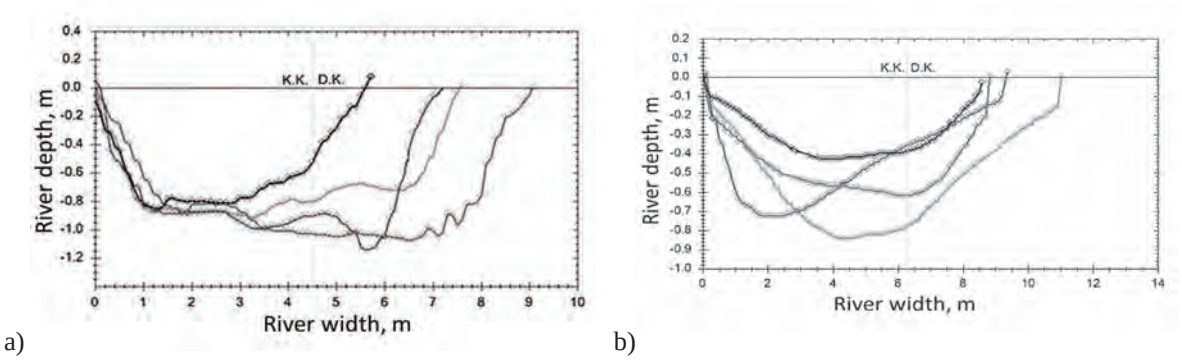
Calculating HBI, each family of macrozoobenthos organisms has tolerance value, which ranges from 0 to 10. HBI tolerance values were taken from Mandaville (2002).

In the rivers, species composition, abundance and biomass of fish were assessed by electric fishing method (using produced by HANS GGRASSL GmbH (Germany), tested and registered by the set in Lithuania order electric fishing machine of IG 200/2B series). Ecological status of rivers was assessed according to fish community structure index of the ecological status of Lithuanian rivers (LFI).

Results and Discussion

Flow rates in the researched natural beds were determined to be higher, but mean cross sections of riverbeds were by 1.2 – 1.9 times smaller in comparison with the regulated ones. It was found out that in natural riverbeds transverse profiles have a characteristic parabolic shape, often spilling over from symmetric to asymmetric (Figure 2).

The surface is smooth, without abrupt changes in the bottom shape. Meanwhile, the shape of regulated riverbeds can be distributed into having broken and relatively smooth surfaces. It was found out that riverbeds with broken profiles are characterized by naturalization processes, while those having smooth shape are characterized by insignificant naturalization processes. The shape of regulated riverbeds is also parabolic, but the main difference from the natural beds is that the parabolic profile along the bed is symmetric. Thus, the flow distribution is more even throughout the bed of such cross-section. In the studied natural riverbeds the distribution of wet perimeter is by 1.2 to 1.4 times higher than that of regulated watercourses. Although in the natural riverbeds mean values of hydraulic radii were set by 32 – 63% lower compared to the regulated ones, however, higher by 1.8 to 3.9 times spread of hydraulic radii was ascertained in the natural riverbeds.



a) b)

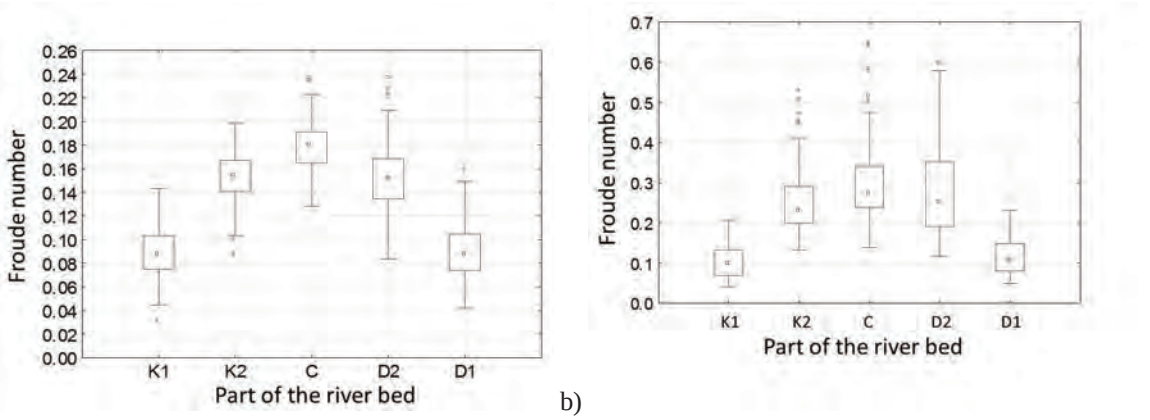
Figure 2. Regulated (a) and natural (b) cross sections of river Gruda.

General distribution of the *Froude number (Fr)* differs substantially in regulated and natural riverbeds (Figure 3).

In the regulated riverbeds the Fr values ranged from 0.0 to 0.20 and the highest Fr value did not exceed 0.25. In natural riverbeds the Fr values usually fluctuated within a larger range (0.0 to 0.35), and its distribution was more even compared to regulated riverbeds. In natural riverbeds a twice wider range of Fr values was ascertained. The Fr values determined in natural riverbeds comprise 0.50 (*Spengla NM*) or even 0.65 (*Amarnia NM*), while in regulated ones do not exceed 0.25. Exception is *Cirvija RM*, where the riverbed has actually recovered, and Fr in it fluctuated up to 0.60. In individual sections of regulated riverbed parts (especially *K2, C, D2*) the distribution of Fr values is lower in comparison with natural riverbeds. In *K1* and *D1* riverbed parts, located at the shoreline, distribution of Fr values is higher in comparison with the *K2, C,* and *D2* parts located closer to the axial riverbed line. This is mostly influenced by the cover and density of herbaceous and woody vegetation. We can see that differences between regulated and natural beds are due to morphology.

In the sections of the studied four rivers 105 taxa of macroinvertebrates belonging to 56 families were identified. Studies have shown that regulated river segments differed from the natural ones by dominant macroinvertebrate species. The data suggest that chironomids prevailed in the regulated river sections. Among them more numerous were *Cricotopus algarum*, *Cladotanytarsus sp.*, *Polypedilum scalaenum*. In the studied *Amarnia RL* (May, September) and *Spengla RL* (May, June) river sections mayflies *Caen macrura*, which in *Spengla NM*, *Gruda NM* and *Cirvija RM* river sections were not identified, were abundant there, while in the river section of the *Amarnia NM* single individuals were found only in May and June samples. According to the study results, caddisfly species *Brachycentrus maculatus* in *Amarnia RL* and *Spengla RL* sections were not found.

It was ascertained that mean abundance of macrozoobenthos in the same section of regulated river was statistically significantly lower than in the natural river segment. Statistically significant differences between the abundance of macroinvertebrates in the fields and woods of the regulated river segments have not been identified. According to the data of Kennedy



a) b)

Figure 3. The distribution of Froude number in regulated (a) and natural (b) stretches of river Amarnia.

Table 2

Ecological condition of the studied sections of rivers by LFI method

River	LFI	Status
Amarnia NM	0.920	Good
Grūda NM	0.925	Good
Spengla NM	0.914	Good
Cirvija RM	0.919	Good
Cirvija RL	0.662	Average
Grūda RL	0.512	Average
Amarnia RL	0.226	Bad
Spengla RM	0.242	Bad
Spengla RL	0.036	Very bad

(2012), abundance of macrozoobenthos in the regulated river segment was by 50% lower than in the natural one.

The biggest number of EPT macroinvertebrate taxa during the research period was recorded in natural riverbeds (*Amarnia NM, Cirva RM, Gruda NM, Spengla NM*), but the lowest - in the fields of the regulated segments. Scientists have demonstrated that the representatives of *Plecoptera* (early) order are more sensitive to the impact of human and structural changes of the natural environment than the representatives of *Ephemeroptera* (mayflies) or *Trichoptera* (caddis) orders (Fore et al., 1994; Maxted et al., 2000). The data showed that in the *Amarnia RL* section caddis were not found during the whole study period, while in the fields of regulated sections of other rivers their abundance was low.

In all natural river sections water quality according to HBI was excellent or very good. In regulated river sections in the field condition according to HBI ranged from good to bad. The worst state according to HBI was ascertained in *Grūda RL* section in May and in *Spengla RL* section in September, November.

However, according to the research it was found out that physical - chemical water quality parameters in the studied sections corresponded to good and very good condition; thus, macrozoobenthos abundance and species composition were influenced by other factors. Likely, it has been influenced particularly by hydromorphology and flow energy transport as well as distribution in riverbeds.

In the studied river sections a total of 16 species of fish and lamprey have been recorded. Comparing fish communities of all studied natural and regulated sections of rivers, their species composition varies substantially. In all studied natural river sections, to the environmental quality changes such species as trout and goby reside very sensitively (NTOLE). Typical river fish (minnow, goby, loach, trout) is dominating, for the spawning and egg development of which pebbly, well-aerated soil is essential.

According to Lithuanian fish index for the assessment of river status, ecological condition of all the researched natural sections of rivers is good (Table 2).

Good ecological status is recorded for flowing through the forest, almost recreated *Cirvija RM* section. Condition of the remaining, regulated sections of rivers varies from average (*Cirvija RL* and *Grūda RL*) to poor (*Amarnia RL* and *Spengla RM*) or even very bad (*Spengla RL*). The lowest LFI values (the worst ecological status) was recorded in regulated sections, where the shoreline woody vegetation has been completely destroyed (*Amarnia RL* and *Spengla RL*).

In regulated sections, by contrast, dominate not demanding to the habitat structure, adaptable to various types of environment fish: perch, pike, roach (the latter species found only in regulated river sections).

Overall diversity of fish species in natural sections of rivers is almost 2 times higher than in regulated ones, and these differences are statistically significant (*t* test, p=0.008). Total density of fish in natural river sections was found on average four times higher than in regulated ones and these differences are statistically significant (*t* test, p=0.015).

Conclusions

1. Based on the derived statistical models, it was found out that in natural beds mean cross section area was by 1.2-1.9 times smaller compared to regulated one, while the variation of this parameter along the riverbed was usually 1.2 to 2.3 times higher in natural beds. The shape of natural beds is parabolic, often spilling over from the symmetrical shape to asymmetrical. In regulated beds broken and symmetrical parabolic profiles were predominating.
2. The distribution of flow energy estimated by Froude number (*Fr*) substantially differs in regulated and natural beds. In regulated beds the ascertained *Fr*

values usually ranged from 0.0 to 0.20, while the highest *Fr* value did not exceed 0.25. In natural beds the determined *Fr* values fluctuated in a larger range (0.0 to 0.35) and its distribution was more even in natural as compared to regulated beds.

3. In the studied sections of rivers 105 taxa of macroinvertebrates belonging to 56 families were identified. The biggest number of EPT macroinvertebrate taxa during the research period was recorded in natural riverbeds (*Amarnia NM, Cirva RM, Gruda NM, Spengla NM*), and the lowest - in the fields of the regulated segments.
4. Comparing fish communities in natural and regulated sections of rivers, the composition of species varies substantially. Trout and goby which are hypersensitive (NTOLE) to environmental quality change fish species were found reside in all researched natural river sections. In regulated beds these species have not been detected. In regulated sections, by contrast, dominate not demanding to habitat structure, adaptable to various types of environment fish: perch, pike, and roach. Total diversity of fish species in natural sections was nearly two times higher than in regulated ones. Total fish density in natural river sections was determined on an average by 4 times higher than in regulated ones.

References

1. Althaus J.M., Cesare G., Schleiss A.J. (2008) Release of sediment laden water through power intakes of deep reservoirs. In *Proceedings Of International Conference River Flow.* Turkey. September 3 – 5, pp. 1173 – 1180.
2. Angermeier P.L., Karr J.R. (1983) Fish communities along environmental gradients in a system of tropical streams. *Environmental Biology of Fishes*, 9, pp. 117 – 135.
3. Angermeier P.L., Schlosser I.J. (1989) Species area relationships for stream fishes. *Ecology*, 70, pp. 1450 – 1462.
4. Arbačiauskas K. (2009) Bentoso makrobestuburiai. (Benthic macroinvertebrates). *Gyvūnijos monitoringo metodai*. (*Wildlife monitoring methods*.) Vilnius: VU Ekologijos institutas, pp. 22 – 45. (in Lithuanian).
5. Campisano A., Creaco E., Modica C., Rietano S. (2008) Temporal evolution of the filling process of closed check dams Laboratory experiments and numerical modeling. In *Proceedings Of International Conference River Flow.* Turkey. September 3–5, pp. 1389 – 1397.
6. Fore L.S., Karr J.R., Conquest L.L. (1994) Statistical properties of an index of biotic integrity used to evaluate water resources. *Canadian Journal of Fisheries & Aquatic Sciences*, 51, pp. 1077 – 1087.
7. Gailiušis B., Jablonskis J., Kovalenkovienė M. (2001) *Lietuvos upės: hidrografija ir nuotėkis. (Lithuanian rivers: hydrography and runoff).* Kaunas: Lietuvos energetikos institutas. 796 p. (in Lithuanian).
8. Gonzalez J., Tamburinno A., Nino Y. (2008) A discussion on the role of particle settling velocity on equations goveming turbidity currents. In *Proceedings Of International Conference River Flow.* Turkey. September 3 – 5, pp. 1139 – 1146.
9. Gorman O.T., Karr J.R. (1978) Habitat structure and stream fish communities. *Ecology*, 59, pp. 507 – 515.
10. Hilsenhoff W.L. (1988) Rapid field assessment of organic pollution with a family-level biotic index. *Journal of the North American Benthological Society,* 7, pp. 65 – 68.
11. Horsák M., Bojková J., Zahrádková S., Omesová M., Heleśic J. (2009) Impact of reservoirs and channelization on lowland river macroinvertebrates: a case study from central Europe. *Limnologica,* 39, pp. 140 – 151.
12. Huet M. (1959) Profiles and biology of Western European streams as related to fish management. *Transaction of the American Fisheries Society*, 88, pp. 155 – 163.
13. Kemp J.L., Harper D.M., Crosa G.A. (2000) The Habitat-Scale Ecohydraulics of Rivers. *Ecological Engineering*, 16(1), pp. 17 – 29.
14. Kennedy R., Crozier W., Allen M. (2012) The effect of stocking with 0+ year age-class Atlantic salmon Salmo salar fry: a case study from the River Bush, Northern Ireland. *Journal of Fish Biology,* 81, pp. 1730 – 1746.
15. Mandaville S.M. (2002) *Benthic macroinvertebrates in freshwaters. Taxa tolerance values, metrics, and protocols*. Project H-1: Soil and water conservation society of metro Halifax. XVIII, 48p.
16. Maxted J.R., Barbour M.T., Gerritsen J., Poretti V., Primrose N., Silvia A., Penrose D., Renfrow R. (2000) Assessment framework for Mid-Atlantic coastal plain streams using benthic macroinvertebrates. *Journal of the North American Benthological Society*, 19, pp. 128 – 144.
17. Nakamura F., Yamada H. (2005) The effects of pasture development on the ecological functions of riparian forests in Hokkaido in Nothern Japan. *Ecological Engineering,* 24, pp. 539 – 550.

18. Oberdorff T., Guilbert E., Luchetta J.C. (1993) Patterns of fish species richness in the Seine River basin, France. *Hydrobiologia*, 259, pp. 157 – 167.
19. Rahel F.J., Hubert W.A. (1991) Fish assemblages and habitat gradients in a Rocky Mountain-Great Plains stream: biotic zonation and additive patterns of community change. *Transactions of the American Fisheries Society*, 120, pp. 319 – 332.
20. Rosenberg D.M., Mccully P., Pringle C.M. (2000) Global-scale environmental effects of hydrological alternations: introduction. *Bioscience*, 50, pp. 746 – 752.
21. Schlosser I.J. (1982) Fish community structure and function along two habitat gradients in a headwater stream. *Ecological Monographs*, 52, pp. 395 – 414.
22. Vaikasas S., Pliūraitė V., Palaima K. (2011) Slenkstinių užtvankų ant lygumų upių poveikio vandens organizmams tyrimai ir vertinimas (Impact of Overflow Dams on Aquatic Organisms in Plain Rivers). *Vandens Ūkio Inžinerija,* 39, pp. 34 – 45. (in Lithuanian).

PROSPECTS OF A PNEUMATIC PULSE METHOD OF DEHYDRATION OF THE SEWAGE SLUDGE

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Abstract
The most efficient way to dewater sewage sludge is the thermal drying, which simultaneously with the granulation allows obtaining the product in the form of granules, being a non-putrescible fertilizer that is also easy for transportation, storage and bringing into soil. When large volumes of sewage sludge are formed, which are unfit for use in agriculture, application of other utilization methods, such as burning, would be purposeful. The aim is to determine the optimum drying modes of sewage sludge with application of pneumatic pulse method at treatment facilities in the pilot project. To do this, it is necessary to develop a proposal for the design of operating model. The design and making of working model is necessary to determine the optimal conditions for sewage sludge drying at sewage disposal works. The drying process is provided to be realized in a closed-loop cycle (without emission into atmosphere). Due to inner recirculation of dry air, the installation heat consumption is reduced. Calculations have shown that there is economic expediency of using the pneumatic pulse method in sewage sludge thermal drying technology and possibility of using sewage sludge as an alternative fuel. Optimization of sewage sludge thermal drying process with the use of pneumatic pulse method will considerably extend the perspectives for utilization and further use of sewage sludge.
Key words: sewage sludge, pneumatic pulse method, dehydration of the sewage sludge, alternative fuel.

Introduction

Utilization of the sewage sludge (SS) is pressing, and it is crucial environmental and economic challenge. The task of the modern technology on treatment of the SS is to meet the contemporary challenge and transform SS into the environmentally safe product as well as apply the SS valuable components with the significant reduction of the sludge amount as a result of dehydration (Gusarevs, 2013). Reductions of energy consumption and capital investments during SS processing and recycling actions also have significant importance.

It is possible to distinguish the following main directions of the SS utilization:

- fertilization of the soil;
- burning;
- disposal (Gemste and Vucāns, 2010; Bārdule et al., 2011; Lazdiņa et al., 2011).

Utilization of SS, which is associated with their use in agricultural industry, is determined by their content of biogenic elements.

As a fertilizer, such SS may be used, which has been a subject to treatment that guarantees their subsequent non-putrescibility as well as the death of pathogenic microorganisms and helminth eggs, in accordance of the Cabinet Council No. 362 of May 2, 2006 (Noteikumi par notekūdeņu dūņu un to komposta izmantošanu, monitoring un kontroli, 2006).

The most efficient way to dewater SS is thermal drying, which simultaneously with the granulation allows obtaining the product in the form of granules, being a non-putrescible fertilizer that is also easy for transportation, storage and bringing into soil (Lazdiņa et al., 2013).

Possibility should be also taken into consideration that SS contains harmful substances, in particular the salts of heavy metals, chemicals, etc., which are subjected to a strict control over content of harmful substances in the ready product and its further use in agriculture as a fertilizer (Lazdiņa et al., 2007).

When large volumes of SS are formed, which are unsuitable for use in agriculture, application of other utilization methods, such as burning, would be purposeful.

SS may be considered as an alternative source of energy. The use of SS energetic potential should be economically reasonable. Calorific capacity of dry SS substance is 3 to 5 MJ kg^{-1}, which mainly depends on the ash content. Ecological problems of SS incineration are associated with flue-gas emission.

Thermal drying is mainly used at large sewage disposal works with the purpose to increase the calorific capacity of SS in the process of their further incineration. Thermal drying of SS for the use in agriculture is rarely applied due to high costs.

Application of pneumatic pulse method in the dewatering technology during the SS utilization allows us to considerably decrease the power consumption costs and capital investments. Carrying out the drying process at lower temperatures lets us to retain more biogenic elements.

The aim of this paper is to determine the optimum drying modes of SS with application of pneumatic pulse method at treatment facilities in the pilot project. It is necessary to develop a proposal for the design of acting model.

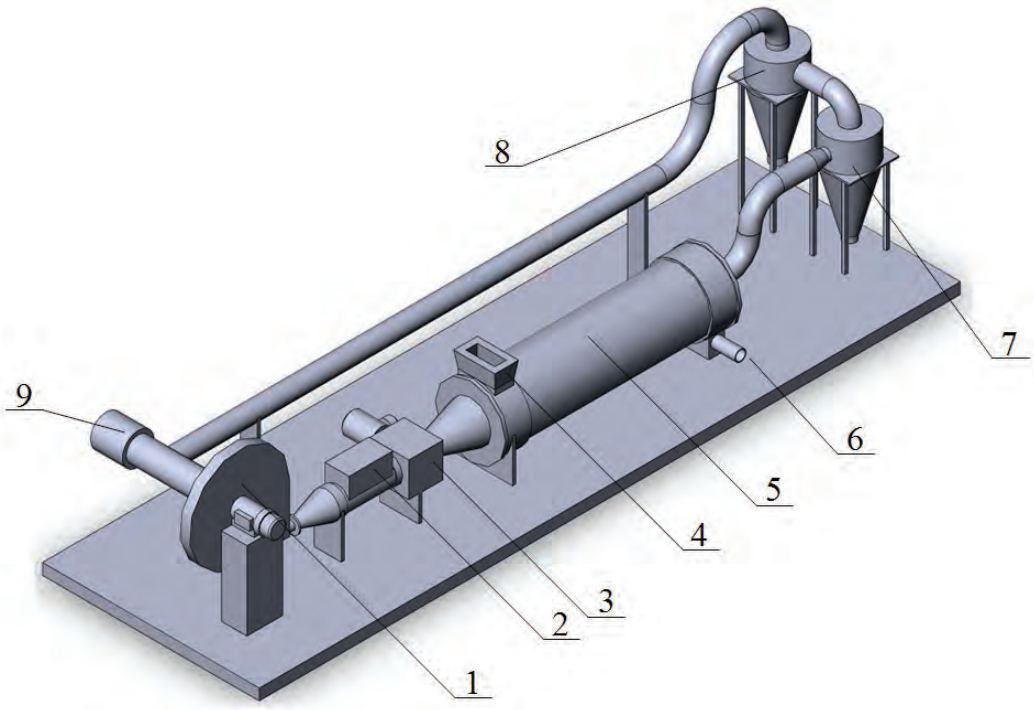

Figure 1. Scheme of the acting model.
1 – a blower; 2 – an electric heat generator; 3 – a pulser; 4 – a loading hatch; 5 – a drying chamber; 6 – an unloading hatch; 7 – a cyclone; 8 – a hydraulic cyclone; 9 – an air valve.

Materials and Methods

Based on data obtained from experimental module for SS drying with application of pneumatic pulse method, a proposal was developed for the design of acting model (Gusarevs, 2013). The scheme of the acting model is shown in Figure 1.

The design and making of operating model is necessary to determine the optimal conditions for SS drying at sewage disposal works. The drying process is provided so that it can be realized in a closed-loop cycle (without emission into atmosphere). Due to inner recirculation of dry air, the installation heat consumption is reduced.

The following significant indicators were taken into consideration when developing the proposal:

- investment expenses for drying equipment;
- service life and operational load of equipment;
- SS dewatering degree;
- power consumption in the drying process;
- SS calorific capacity;

Table 1

Calculations of different drying processes

Parameter	Unit	Value (without pulser)	Value (with pulser)
Capital investment	EUR	500000	500000
Equipment productivity*	$m^3\ day^{-1}$	8	8
Guaranteed operation	days $year^{-1}$	min.342	min.342
Humidity at the inlet	g kg^{-1}	860	860
Humidity at the output	g kg^{-1}	300	300
Electric power expended**	kW L^{-1} H_2O	0.07	0.04
Received power	kWh	1,1	1,1
Equipment service life	year	15	15
Payback	year	12	6 -10

* Equipment productivity adopted according to PE 20000 (person equivalent).
** Costs are calculated on the evaporation of 1 L of water.

- SS specific weight.

Determination and control of the following parameters are provided for:

- speed, pressure and volume of air flow;
- temperature conditions;
- humidity of material to be dried out;
- pressure in drying chamber;

The studies should be further continued within the pilot project framework in order to identify the peculiarities of SS drying conditions in production environment.

Results and Discussion

Calculations performed are shown in Table 1. Performed calculations have shown:

- economic expediency of using the pneumatic pulse method in SS thermal drying technology;
- possibility of using SS as an alternative fuel;
- reduction of energy costs with the use of pneumatic pulse method in SS thermal drying technology;
- repayment of capital investments during the equipment operation period.

Conclusions

Optimization of SS thermal drying process with the use of pneumatic pulse method will considerably extend the perspectives for utilization and further use of SS. The studies should be further continued within the pilot project framework in order to identify the peculiarities of SS drying conditions in production environment.

References

1. Bārdule A., Rancāne S., Gūtmane I., Bērziņš P., Stesele V., Lazdiņa D., Bārdulis A. (2011) The effect of fertilizer type on hybrid aspen increment and seed yield of perennial grass cultivated in the agroforestry system. *Agronomy Research 11 (1)*, pp. 13 – 25.
2. Gemste I., Vucāns A. (2010) *Notekūdeņu dūņas.* (Sewage sludge). Otrais papildinātais izdevums. Latvijas Lauksaimniecības universitāte, Jelgava, 276 lpp. (in Latvian).
3. Gusarevs I. (2013) Advantages of the pneumatic pulse method for dehydration of the sewage sludge. A*nnual 19th International Scientific Conference Proceedings „Research for Rural Development 2013" Volume No. 2*, Latvia University of Agriculture, Jelgava, Latvia, pp. 148 – 152.
4. Lazdiņa D., Lazdiņš A., Kariņš Z., Kāposts V. (2007) Effect of sewage sludge fertilization in short-rotation willow plantations. *Journal of environmental engineering and landscape management,* 15, pp. 105 – 111.
5. Lazdiņa D., Bārdule A., Lazdiņš A., Stola J. (2011) Possibilities to utilize waste water sludge and wood ash as fertilizer for Salix cultivation on acid peat soils. *Agronomy Research 9 (1-2)*, pp. 305 – 314.
6. Lazdiņa D., Liepiņš K., Bārdule A., Liepiņš J., Bārdulis A. (2013) Wood ash and wastwater sludge recycling success in fast-growing decidious tree – birch and alder plantations. *Agroonmy Research 11 (2),* pp. 347 – 357.
7. Noteikumi par notekūdeņu dūņu un to komposta izmantošanu, monitoringu un kontroli. (Terms of sewage sludge and compost utilization, monitoring and control) (2006) LR Ministru kabineta noteikumi Nr. 362. Available at: http://www.likumi.lv/doc.php?id=134653, 12 March 2014. (in Latvian).

STREAMS WATER QUALITY ANALYSIS IN MANURE FERTILIZED FIELDS

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Abstract

The research was conducted during the period of 2007-2011 in the fields fertilized by manure of pig breeding complex. According to the fertilization value of manure, the following total nitrogen levels reached the fields each year: 2007 – 169, 2008 – 167, 2009 - 168, 2010 - 168, 2011 – 168 kg ha^{-1}. P_{total} reached the fertilized fields accordingly: 2007 – 9.4, 2008 – 18.9, 2009 – 12.0, 2010 – 10.8, 2011 – 13.5 kg ha^{-1}.

The aim of the research was to explore the impact of manure fertilized fields of a pig breeding complex on the water quality of streams.

Streams, flowing through fields fertilized with manure, are usually polluted with nitrogen. The increase in N_{total} concentrations in streams' water below fertilized fields was affected by precipitation (r = -0.31), fertilization rate (r = 0.41) as well as mineral nitrogen reserves in the soil (r = 0.20).

Phosphorus concentrations in streams' water were low and corresponded to a very good streams' water ecological condition, except in times, when the water inflowing into the fertilized fields was already contaminated with this element. It was determined that an extremely high impact on streams' water quality below fertilized fields comes from P_{total} concentration in streams' water above fertilized fields (r = 0.91) as well as from the drainage water inflowing from fertilized fields into the streams (r = 0.71).

Neither N_{total}, nor P_{total} pollution was observed in drainage water, because the highest concentrations during the research period were lower than the maximum allowable concentrations by 1.1 and 6.5 times respectively.

Key words: fertilize, manure, nitrogen, phosphorus, stream.

Introduction

In 1991 the Nitrates Directive was adopted, which is one of the first EU acts of legislation, intended for the control of pollution and the improvement of water quality. All 27 Member States, following the directive, must analyse the concentration level of nitrates and trophic state in their waters. Every four years the European Commission, referring to the information obtained from national institutions, prepares a report about the implementation of the directive.

It is stated in the latest report by the Commission to the Council and the European Parliament that the surface water quality, taking into account nitrates concentration, has improved. In comparison to the previous (2004 – 2007) reporting period, during the current period (2008 – 2011) in only 3% of monitoring stations the concentrations of nitrates exceeded 50 mg L^{-1}, and in 2.9% of monitoring stations this indicator constituted from 40 mg L^{-1} to 50 mg L^{-1}. The average values of samples taken in winter exceeded the concentration of nitrates by 25 mg L^{-1} in 2.9% of stations, and in 2.4% of stations this indicator was higher than 50 mg L^{-1}. The lowest annual nitrates' concentration in fresh surface water was found in Finland and Sweden, as well as in Lithuania, Portugal, and the Netherlands, while the highest – in Malta, the UK, and Belgium, where the concentration of nitrates in majority of stations exceeds 40 mg L^{-1} (Komisijos..., 2013).

During the development of an intensive stockbreeding, it is not always possible to ensure water quality. A large number of livestock in a certain territory raises a real danger to the environment, because the production of manure is disproportionally high compared with the used land and the need to grow cultivated crops. Because of the absence of such balance, an excess of nutrients forms, whose large part, if not removed from the site, sooner or later access the water (Komisijos..., 2013). It is stated in the water framework directive, that, due to the non-point pollution, it is extremely difficult to ensure a good water quality (Europos..., 2000). The Europe's water resources conservation framework adopted due to this reason states that Nitrates Directive is still one of the main measures used to achieve the goals set out in the Water framework directive (Komisijos..., 2012).

Each year, the ongoing Lithuanian surface Water bodies' monitoring data shows that the country's water bodies' ecological condition is improving. Curonian Lagoon is the biggest and highly ecologically important Lithuania's inland water body, whose ecosystem's state extremely depends on pollutant loads' inflow from the basins of rivers, where the main one is Nemunas river. The evaluation of the 2012 monitoring data showed, that the inflow of total phosphorus into the Curonian Lagoon has decreased by 12%, compared to the year 2011, and the indicator of consumption of total nitrogen and biochemical oxygen during 7 days has increased (Aplinkos..., 2013).

Surface water bodies' quality is currently being assessed according to "The Surface Water Bodies' State Evaluation Methodology" approved by the Minister of Environment of the Republic of Lithuania (Lietuvos..., 2010). According to this methodology, the ecological state of rivers is divided into 5 classes

from a very good state, when N_{total} <2, P_{total} <0.1 to a poor state, when N_{total} >12, P_{total} >0.47 mg L^{-1}.

From the fields being polluted the concentrations of polluting substances in the effluent drainage water must not exceed these maximum allowable concentrations: N_{total} – 15, P_{total} – 2 mg L^{-1} (Lietuvos..., 2012).

One of the most dangerous pollution sources is the intensive production stockbreeding objects, whose production waste effect on the soil and water quality is still not extensively researched. According to the data from the Lithuanian Geological Office, it was found that pig breeding farms or complexes operate in 31 municipality (Giedraitis, 2011).

Studies have shown that storing large livestock herds in one area (around 750 livestock units - LSU), results in a much higher ground water pollution per 1 LSU than storing smaller livestock herds in the same area (Kutra et al., 2007).

Scientists claim that the relationship between water quality fluctuations in streams depending on various factors in their pools is extremely difficult to determine (Vagstad et al., 2001). It was found that non-point water pollution is directly related to the usable fertilizer amount, grown crops, and the general farming culture (Meissner et al., 1998). Constantly produced crops of one type also impact a higher nitrogen migration in the profile of the soil (Bakhsh et al., 2001).

It was revealed that the leaching of nitrogen is highly affected by natural factors, the soil's composition, the density of livestock, lea amount: however, local factors affect it the most (Howarth et al., 2012; Kyllmar et al., 2006).

The study on the manure fertilized fields of the pig breeding enterprise has shown that during the research period on average 11.4 t of nitrogen and 0.073 t of phosphorus has leached into the river through the drainage water. Most pollutants have leached during the cold time of year, when crops do not vegetate: nitrogen – 68.6, phosphorus – 60% of the annual amount (Strusevičius et al., 2009). This confirms the propositions that the most nitrogen is lost during autumn and winter seasons, because during this time the majority of Lithuania's soil areas are without the cover of crops (Tripolskaja, 2005). It was revealed that the biggest quantities of mineral biogenic materials flow into the sea in winter time, while the least – in summer time. The second highest amount value of mineral nitrogen was observed in spring, and mineral phosphorus – in autumn (Dubra et al., 1999).

The scientists from the UK, who have conducted a long-term research, claim that the majority of nitrates, which are polluting water pools, access water when the organic soil nitrogen resolves. For this reason, by reducing fertilization, the problem of polluting the water with nitrates is not solved.. It can start operating after a long time, when the organic material in the soil will reduce. However, the benefit of the leaching reduction of nitrate nitrogen will not be significant, compared with the losses, which will be incurred by the farmer – producer (Addiscott, 1998; Dunn et al., 1999). The studies in Eastern Germany have shown that agricultural extensification causes a large increase in leaching of elements and compounds in less than a year, compared with areas, with intensive farming (Meissner et al., 1998).

It was agreed almost unanimously that the leaching of elements and compounds as well as unproductive fertilizer losses extremely increase by fertilizing crops more than needed. Therefore, both soil and water pollute as much as crops do not use up, even though the fertilizer is intended for crops' nutrition (Jaynes et al., 2001; Bučienė, 2009).

The aim of the research was to explore the impact of manure fertilized fields of a pig breeding complex on the water quality of streams.

Materials and Methods

Research was conducted during the period of 2007 – 2011 in Raseiniai district, in swine manure fertilized fields of "Girkalnio kiauliu kompleksas", Ltd. (Fig.1).

Water samples were taken from the following areas:

- No. 1 – the river Berztupis above the sources of pollution;
- No. 2 – a drainage system collector to the river Berztupis;
- No. 3 – the river Berztupis below the sources of pollution;
- No. 4 – the river Apusinas above the sources of pollution;
- No. 5 – a drainage system collector to the river Apusinas;
- No. 6 – the river Apusinas below the sources of pollution.

For chemical analysis, water samples were taken three times a year – in spring before fertilization, in summer and autumn after fertilization. Water samples from streams were taken above fertilized fields and below them. Drainage samples were taken from drainage systems, which are installed in these fertilized fields. Analyses were carried out in the laboratory 'Labtesta', Ltd.

N_{total} was determined by applying the spectrometric method, by mineralizing with potassium persulphate, P_{total} – by applying the spectrometric method, after mineralization with potassium persulphate.

Soil samples for agrochemical analysis were taken in spring and autumn from 0-60 cm depth at every 30 cm. To identify the content of nitrogen in the soil, the following research methods were

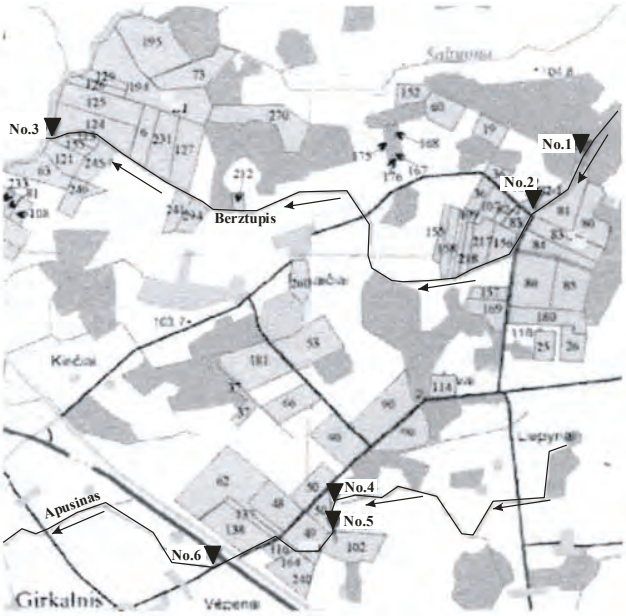

Figure 1. The scheme of fertilized plots of „Girkalnio kiaulių kompleksas“, Ltd (private limited company): No. 1... No. 6 – drainage and surface water locations.

applied: ammonium nitrogen ($N\text{-}NH_4$) – colorimetric with Nessler's reagent in KCl extract; nitrate nitrogen ($N\text{-}NO_3$) — potentiometric with selective electrode. Analyses of $N - NH_4$ and $N - NO_3$ were carried out by means of analyser "FIA Star 5012". To identify phosphorus oxide (P_2O_5), a photo-colorimetric method A-L was applied.

For the fertilization of analysed fields, liquid swine manure was used, which was spread in spring and autumn. The composition of manure was determined from one extract, which was prepared by burning it with concentrated sulphuric acid (H_2SO_4) and selenium (Se) catalyst. Nitrogen was identified by using Kjeldal's method, while phosphorus – by molybdic method. Each year, according to the fertilizing value of manure, the following contents of total nitrogen passed into manure-fertilized fields: 2007 – 169 kg ha^{-1}, 008 – 167 kg ha^{-1}, 2009 – 168 kg ha^{-1}; 2010 – 168 kg ha^{-1}, 2011 – 168 kg ha^{-1}. P_{total} passed into fertilized fields as follows: 2007 – 9.4 kg ha^{-1}, 2008 – 18.9 kg ha^{-1}, 2009 – 12.0 kg ha^{-1}; 2010 – 10.8 kg ha^{-1}, 2011 – 13.5 kg ha^{-1}.

To determine the precipitation and air temperature, Raseiniai meteorological station data was used (Table 1).

It was estimated that most precipitation was in 2007 – 897 mm, and constituted 132% standard climate rate. During the time period 2008 – 2011, precipitation was slightly higher than the climate rate and changed from 102 to 116%.

The average air temperature each year was higher than the standard climate rate, except the year 2010, when it was -0.1 °C lower.

Software: Excel 2000" and "Statistica" were used for the statistical data analysis. The data processing was performed by correlation-regression analysis method.

Results and Discussion

The most important elements, which mostly affect water quality in fertilized fields of swine breeding complexes, are biogenic elements – nitrogen and phosphorus. Even though nitrogen is an essential element for the growth of crops, its large concentration

Table 1

Meteorological conditions of investigation period

Indices	Year				
	2007	2008	2009	2010	2011
Precipitation, mm	897	693	710	762	793
% of the climate standard	132	102	104	112	116
Average air temperature, °C	7.3	7.8	6.6	5.8	7.2
Deviation from the climate standard, °C	+1.4	+1.9	+0.7	-0.1	+1.3

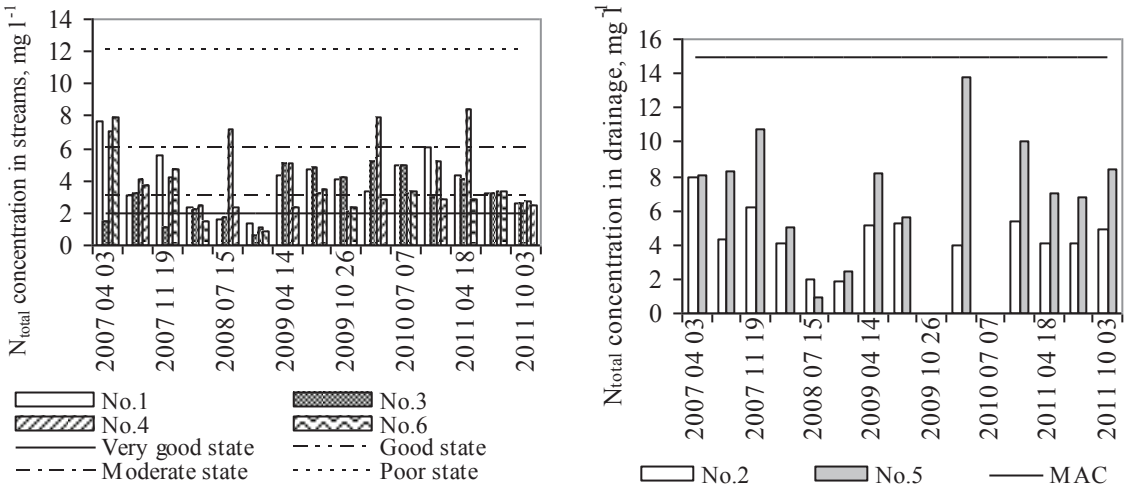

Figure 2. Total nitrogen concentration change in streams' and drainage water.

is harmful to humans and the environment. Nitrogen concentration completely depends on the intensity of biochemical and biological processes occurring in the water. Because of its mobility, nitrogen is found in various inorganic and organic compounds in nature. These compounds show whether water is polluted, they also are toxic. When the water gets more nutrients than needed to crops, eutrophication process starts.

The quality of stream water in terms of total nitrogen concentrations is most often average or poor. The highest concentration values varied between 5.16 to 7.88 mg L^{-1}. Drainage water concentrations corresponded to the requirements for the effluent drainage water from manure fertilized fields; however, as the requirements for drainage water are not as strict as for streams, drainage water flowing into streams can have a negative effect on the water quality of the latter (Fig. 2).

After performing a multiple regression, it was determined that the increase of N_{total} concentrations in drainage water was affected by precipitation, manure fertilized fields' nitrogen reserves in the soil, and fertilization rate. An average correlation between the mentioned factors and drainage water flowing into streams was determined - r = 0.66; n = 26; $F_{theor.95\%}$=3.2 <$F_{fact.}$ = 5.74; p<0.00466 – when p is less than 0.05, then the coefficient is statistically significant at the 95 % confidence level. Similar results were reported by other scientists who claimed that the annual meteorological conditions have a higher effect on the leaching of nitrogen than various ground usage practices (Stalnacke et al., 2002; Bendaravičius et al., 2004). A partial correlation showed an inverse relationship between precipitation and N_{total} concentrations in drainage water (r = -0.18); however, nitrogen reserves in the soil as well as fertilization rate linearly affected N_{total} concentrations in drainage water r = 0.38 and r = 0.30 respectively.

By assessing the drainage water quality according to N_{total} concentrations in drainage water, it was revealed that even the highest of them (13.8 mg L^{-1}) was lower than MAC by 1.1 times.

The impact on the increase of N_{total} concentrations in streams below fertilized fields came from a number of factors: precipitation, fertilization rate, and mineral nitrogen reserves in the soil. After performing the multiple regression analysis on the researched factors, an average correlation was obtained r = 0.55; n = 30; $F_{theor.95\%}$=3.26 <$F_{fact.}$ = 3.77; p<0.02271 – when p is less than 0.05, then the coefficient is statistically significant at the 95% confidence level. Finnish scientists have determined that water quality in small streams depends more on the annual meteorological conditions rather than on ground structure of production or technological changes (Vuorenmaa et al., 2002). A partial correlation determined an inverse relationship between precipitation and N_{total} concentrations in streams' water below fertilized fields (r = -0.31). Fertilization rate had a greater impact on the increase in N_{total} concentrations in the water of streams (r = 0.41) than mineral nitrogen reserves in the soil (r = 0.20).

In order to estimate the N_{total} concentration in the streams below fertilized fields, the following formula can be used:

$$z=-331.369-0.013x_1+2.043x_2+0.025x_3, \quad (1)$$

where z – N_{total} concentration in streams below fertilized fields, mg L^{-1};

x_1 – precipitation during the period of research, mg L^{-1};

x_2 – fertilization rate of total nitrogen, kg ha^{-1};

x_3 – mineral nitrogen reserves in manure fertilized fields, kg ha^{-1}.

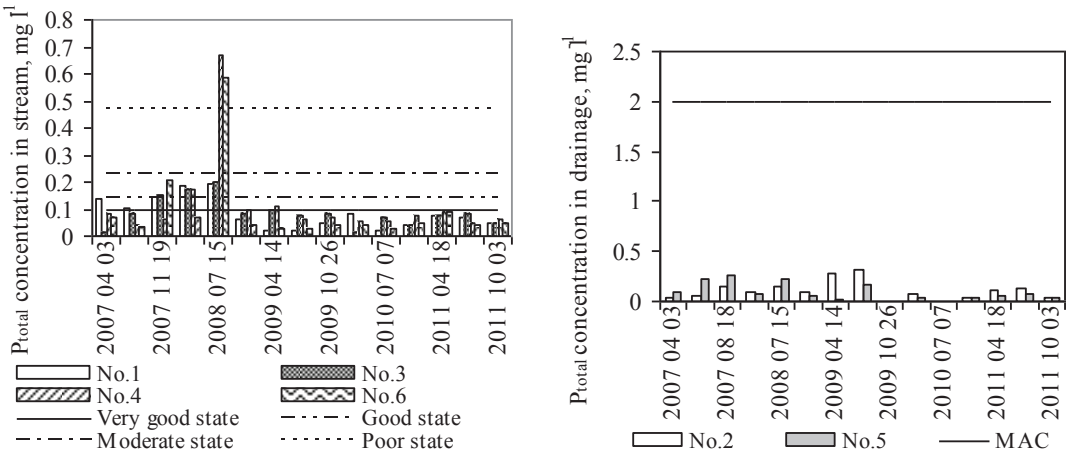

Figure 3. Total phosphorus concentration change in stream and drainage water.

There is only a very small amount of phosphorus in natural water. When concentration of phosphorus in the water increases, water is being polluted; because phosphorus compounds are ascribable to such products, which show that a complex biolysis is taking place in the water.

During the five years of research, total phosphorus concentrations in the water of streams corresponded to a very good water ecological condition, except in 2008, when, due to a higher precipitation, stream water corresponded to a poor (0.586 mg L^{-1}) ecological condition (Fig. 3).

As, during the process of mineralization, the soluble phosphorus is used up by plants, only a small fraction of this element leaches into the drainage water. Large phosphorus reserves in the soil mean that under certain hydrological conditions a lot of it will be leached (McDowell et al., 2004).

In order to find out which factors could have contributed to the increase in P_{total} concentrations in stream water below fertilized fields, a multiple regression analysis was performed, which showed an extremely strong correlation between the precipitation during the research period, P_2O_5 reserves in the soil, fertilization rate of phosphorus, P_{total} concentrations in stream water above fertilized fields, and P_{total} concentrations ($r = 0.95$; $n = 26$; $F_{theor.95\%}=5.2 < F_{fact.} = 37.65$; $p<0.0000$ – when p is less than 0.05, then the coefficient is statistically significant at the 95 % confidence level) in the drainage water, draining from the fertilized fields.

P_{total} concentration below fertilized fields can be estimated according to this formula:

$$z=-2.77849+0.000234x_1-0.000221x_2+0.007282x_3+0.764187x_4+0.444881x_5, \quad (2)$$

where z – P_{total} concentration in streams below fertilized fields, mg L^{-1};

x_1 – precipitation, mm;
x_2 – P_2O_5 reserves in the soil, mg kg^{-1};
x_3 – fertilization rate of phosphorus, kg ha^{-1};
x_4 - P_{total} concentration in streams above fertilized fields, mg L^{-1};
x_5 – P_{total} concentration in drainage water, flowing into streams from fertilized fields, mg L^{-1}.

Data analysis showed that there is weaker relationship between P_{total} concentration in the water of streams below fertilized fields and precipitation ($r = 0.29$), phosphorus reserves in the soil ($r = -0.2$), as well as fertilization rate ($r = 0.30$). It was determined that an extremely high impact on the quality of the water of streams below fertilized fields comes from the P_{total} concentration in stream water above fertilized fields ($r = 0.91$) and the inflowing drainage water ($r = 0.71$).

Drainage water quality was very good, because even the highest observed P_{total} concentrations in drainage water (0.256 mg L^{-1}) and (0.309 mg L^{-1}) were lower than MAC by 7.8 and 6.5 times, respectively.

The increase in P_{total} concentrations in drainage water is related to the precipitation as well as the mobile phosphorus levels in the soil – a strong correlation was determined ($r = 0.89$); $n = 26$; $F_{theor.95\%}=2.23 < F_{fact.} = 44.3$; $p<0.0000$ – when p is less than 0.05, then the coefficient is statistically significant at the 95 % confidence level). Foreign authors claim that the concentrations of phosphorus and their compounds in the drainage water are determined by hydrological conditions (Salazar et al., 2011). The biggest leaching of phosphorus occurs at the initial drainage runoff formation stage in spring and autumn, later concentrations fall and the relationship with drainage runoff weakens (Wesström and Messing, 2007). A partial correlation showed an inverse relationship between the precipitation and P_{total} concentrations in drainage water ($r = -0.75$), while phosphorus reserves

in the soil directly affected P_{total} concentrations in drainage water (r = 0.73).

Conclusions

1. The water quality of streams is mostly negatively affected by total nitrogen. Water quality in the streams during the research period was usually determined as average or poor.
2. An increase in N_{total} concentrations in the water of streams below fertilized fields was affected by precipitation (r = -0.31), fertilization rate (r = 0.41) as well as mineral nitrogen reserves in the soil (r = 0.20).
3. P_{total} concentrations in the water of streams were usually of a very good and good state, except in times, when water flowing to the fertilized fields was already polluted with this element.
4. It was determined that an extremely high impact on the quality of streams water below fertilized fields comes from the P_{total} concentration in the water of streams above fertilized fields (r = 0.91), and an inflowing drainage water from the fertilized fields into streams (r = 0.71).
5. Neither N_{total}, nor P_{total} pollution in drainage water was observed, because the highest concentrations of these elements during the research period were lower than the MAC by 1.1 and 6.5 times respectively.

References

1. Aplinkos apsaugos agentūra (2013) Aplinkos būklė 2012. Tik faktai (Environmental State 2012. Facts only). Environmental Protection Agency. Vilnius, 142 p. (in Lithuanian).
2. Addiscott T. (1998) Farmers fertilizers and the nitrate flood. *New sciences*, pp. 50 – 54.
3. Bakhsh A., Kanwar R.S., Karlen D.L., Cambardella C.A., Bailey T.B., Moorman T.B., Colvin T.S. (2001) N management and crop rotation effects on yield and residual soil nitrate levels. *Soil science,* 166 (8), pp. 530 – 538.
4. Bendaravičius B., Pocienė A., Pocius S. (2004) Drenažo nuotėkio ir nitratų kiekio drenažo vandenyje tyrimai. (Investigation of drainage runoff and the content of nitrates in drainage water). *Vandens ūkio inžinerija*, 26(46), pp. 52 – 56. (in Lithuanian).
5. Bučienė A. (2009) Biogenų N ir P išplova lietuvos žemumų dirvožemiuose. (Leaching of Biogens N and P from Soils of Lithuania‘ Lowlands). Habilitacijos procedūrai teikiamų mokslo darbų apžvalga. Vilnius, 31 p. (in Lithuanian).
6. Dubra V., Styra D., Syrusienė V. (1999) Mineralinio azoto ir fosforo junginiai bei jų kitimas Baltijos jūros Lietuvos pakrantėje ir pasekmės. (Inorganic Nitrogen and Phosphorus in the Lithuanian Baltic Coastal Area: Changes and Consequenses). *Aplinkos inžinerija,* t. 7, Nr. 4, ISSN 1392-1622, pp. 207 – 211. (in Lithuanian).
7. Dunn S.M., Domburg P., Edwards I., Ferrier R.C. (1999) A Simple Modelling Approarch to Identify Processes Controlling Stream Nitrate in an Agricultural Cathment. In *Impact of land use change Nautr. Loads diffuse sources*. Birmingham, pp. 19 – 24.
8. Europos Parlamento ir Tarybos direktyva 2000/60/EB, nustatanti Bendrijos veiksmų vandens politikos srityje pagrindus (European Parliament and Council Directive 2000/60/EB, setting Union‘s action grounds regarding water politics). OL L 327, 2000 12 22, 83 p. (in Lithuanian).
9. Giedraitis R. (2011) Gyvulininkystės kompleksų poveikio požeminiam vandeniui apžvalga. (Livestock Complex Effects on Groundwater Survey). Lietuvos geologijos tarnyba, Vilnius, 37 p. (in Lithuanian).
10. Jaynes D.B., Colvin I.S., Karleen D.L., Cambardella C.A., Meek D.W. (2001) Nitrate loss in subsurface drainage as affected by nitrogen fertilizers rate. *Journal Environmental Quality*, vol. 30, pp. 1305 – 1314.
11. Howarth R., Swaney D., Billen G., Garnier J., Hong B., Humborg C., Johnes P., Morth C.-M., Marino R. (2012) Nitrogen fluxes from the landscape are controlled by net anthropogenic nitrogen inputs and by climate. Frontiers in Ecology and the Environment, 10 (1), pp. 37 – 43.
12. Kyllmar K., Carlsson C., Gustafson A., Ulen B., Johnsson H. (2006) Nutrient discharge from small agricultural catchments in Sweden. Characterisation and trends. *Agric. Ecosyst. & Envir*., 115, pp. 15 – 26.
13. Komisijos ataskaita Tarybai ir Europos Parlamentui (Commission‘s report to the Council and the European Parliament). COM (2012) 673 final. Briuselis, 26 p. (in Lithuanian).
14. Komisijos ataskaita Tarybai ir Europos Parlamentui (Commission‘s report to the Council and the European Parliament). COM (2013) 683 final. Briuselis, 13 p. (in Lithuanian).
15. Kutra G., Gaigalis K. (2007) Požeminio ir drenažo vandens užterštumas azoto junginiais tvartų teritorijose. (Analysis of investigations on underwater and drainage water pollution with nitrogen compounds on farms implementing EU nitrate directive). *Vandens ūkio inžinerija,* 32 (52), pp. 80 – 87. (in Lithuanian).

16. Lietuvos Respublikos aplinkos ministro 2010 m. kovo 4 d. įsakymas Nr. Dl-178 „Paviršinių vandens telkinių būklės nustatymo metodika“. (Surface water bodies' state evaluation methodology). Order of the Minister of Environment of the Republic of Lithuania No. D1 – 178 of March 2010. Valstybės Žinios, No. 29, 1363 p. (in Lithuanian).
17. Lietuvos Respublikos aplinkos ministro ir Lietuvos Respublikos žemės ūkio ministro 2012 m. lapkričio 16 d. įsakymas Nr. D1-939/3D-874. Dėl aplinkos ministro ir žemės ūkio ministro 2005 m. liepos 14 d. įsakymo Nr. D1-367/3D-342 „Dėl mėšlo ir srutų tvarkymo aplinkosaugos reikalavimų aprašo patvirtinimo“ pakeitimo. (Minister of Environment and Minister of Agriculture 2005 July 14 order no. D1-367/3D-342 “Approval of the amendment of manure and slurry management of environmental requirements). Order of the Minister of Environment and the Minister of Agriculture of the Republic of Lithuania 2012 November 16 no. D1-939/3D-874. *Valstybės žinios,* 2012, Nr. 134-6849. (in Lithuanian).
18. McDowell R.W., Sharpley A.N., Condron L.M., Haygarth P.M., Brookes P.C. (2004) Processes controlling soil phosphorus release to runoff and implications for agricultural management. *Nutrient Cycling in Agroecosystems*, 59(3), pp. 269 – 284.
19. Meissner R., Seeges I., Rupp H. (1998) Lysimetr studies in East Germany concerning the influence of set aside of intensively farmed land on the seepage water quality. *Agricultural ecosystems & Environment,* 67, pp. 161 – 173.
20. Salazar O., Wesström I., Joel A. (2011) Identification of hydrological factors controlling phosphorus concentration in drainage water in sandy soils. *J. Soil Sci. Plant Nutr.,* 11 (2), pp. 31 – 46.
21. Stalnacke P., Bechmann M. (2002) Trends in nutrient runoff from agriculture basins in Norway. Agricultural effects on ground and surface waters: research at the edge of science and society, Iss. 273, pp. 267 – 271.
22. Strusevičius Z., Kazakevičienė J., Berankienė L.E. (2009) Upės vandens kokybės pokyčiai žemiau kiaulininkystės įmonės. (Changes in river water quality downstream from the pig complex). *Vandens ūkio inžinerija*, 35(55), pp. 42 – 51. (in Lithuanian).
23. Tripolskaja L. (2005) Organinės trąšos ir jų poveikis aplinkai. (Organic fertilizer and its impact on the environment). Lietuvos žemdirbystės institutas. 214 p. (in Lithuanian).
24. Vagstad N., Stalnacke P., Andersen H.E. (2001) Nutrient losses from agriculture in the Nordic and Baltic countries – Measurements in small agricultural catchments and national agro-environmental statistics. Nordic Council of Ministers, *TemaNord*, 591, pp. 15 – 48.
25. Wesström I., Messing I. (2007) Effects of controlled drainage on N and P losses and N dynamics in a loamy sand with spring crops. *Agric. Water Manage*., 87, pp. 229 – 240.
26. Vuorenmaa S., Rekolainen S., Lepisto A., Kenttamies K., Kauppila P. (2002) Losses of Nitrogen and Phosphorus fro Agricultural and Forest Areas in Finland during the 1980s and 1990s. *Environ. Monit. Assess*., 76, pp. 213 – 248.

ROLE OF AGRICULTURE ON REGIONAL VARIATION OF PARLIAMENTARY ELECTION RESULTS IN LATVIA

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Abstract
The main objective of this research is to find out if quantitative factors describing agriculture have a statistically significant role on the parliamentary election results in Latvia. If this statistical relationship can be proven, then it is important to interpret the causality behind it.
18 agricultural indicators from the 2001 Census of Agriculture were selected to be analyzed with the 8th Saeima political party election results by using multiple linear regression analysis. These 18 parameters are different in their character, and they describe the size of farms, level of education for farmers, land usage statistics, proportion and productivity of certain crops, livestock and the usage of farm machinery.
The main hypothesis of this research was that the rural civil parishes with a high intensity of agriculture have a statistically significant difference in election results when compared to the rest of the election results in Latvia. Initial results showed a strong correlation between election results and agricultural indicators, but when the ethnic factor was taken into account in the linear regression model the role of these agricultural indicators was greatly diminished.
Key words: electoral geography, Census of Agriculture, multiple regression analysis.

Introduction

Spatial variation of parliamentary election results in Latvia has been influenced by a variety of factors. These factors differ from each other in the extent of their influence, where some factors have a much greater role than others. For example, ethnic factor is the most important factor that influences election results (Paiders and Paiders, 2011) and it is more important than urban–rural differences that influence the election results in Latvia to a much lesser amount (Paiders and Paiders, 2013). These factors that influence the results of political parties also can be categorized by their impact on the course of many elections. Most of the factors have a steady influence with a relatively small change amongst different elections, but there are some factors whose influence varies over time. For example, the role of regional candidates has increased after the 10th Saeima elections, because after that it became impossible to be a candidate in multiple electoral districts and it increased the role of local candidates with limited geographical area of influence.

Quantitative research in finding out the full variety of factors that influence Saeima election results in Latvia can be problematic, because of the huge role of the ethnic factor in Latvian politics. The explained proportion of the dispersion of political party results this factor explains is so large that it is complicated to gain statistically significant results about other factors that influence the election results.

The main objective of this research is to find out if quantitative factors describing agriculture have a statistically significant role on the parliamentary election results in Latvia and if this statistical relationship can be proven, then it is important to interpret the causality behind it. Agricultural indicators were used from the 2001 Census of Agriculture (Centrālā Statistikas Pārvalde, 2003) where a total of 176 parameters were obtained. These results were analyzed on a local level (civil parishes) comparing them with the 8th Saeima election results (atsauce) because these elections were the closest in terms of time to the 2001 Census of Agriculture. The reason why newer agricultural data was not used is because 2001 was the last year of agricultural census when the results were published on a civil parish level. The 2010 Census of Agriculture was published on a county level which vastly reduces the size of the analyzed data. The main hypothesis of the research was that rural civil parishes with a high intensity of agriculture have a statistically significant difference in election results when compared to the rest of the election results in Latvia.

Materials and Methods

The study analyzes the officially approved results of the elections of the 8th, 9th, 10th and 11th Saeima (parliament) of the Republic of Latvia (Centrālā Vēlēšanu Komisija, 2011). The results of all political parties participating in the parliamentary elections were acquired and analyzed, but for parties having overcome the 5% threshold the level of analysis was more detailed. In the 8th Saeima elections 6 political parties overcame this threshold: "For Fatherland and Freedom/LNNK" (TBLNNK), "For Human Rights in United Latvia" (PCTVL), "New Era Party" (JL), "People's Party" (TP), "Latvia's First Party" (LPP) and "Union of Greens and Farmers" (ZZS). In this paper abbreviations for these parties were used.

Only the rural parishes where there was agricultural census data available were included in the research with a total of 481 analyzed civil parishes. From the 176 obtained parameters describing agriculture only

18 were selected to be analyzed with the political party election results in order to reduce the collinearity and similarity of the agricultural parameters. These 18 parameters differ in their character and they describe the size of farms, level of education for farmers, land usage statistics, proportion and productivity of certain crops, livestock and the usage of farm machinery.

In this research, the result of every political party who overcame the 5% threshold in the 8th Saeima elections was analyzed with those 18 parameters by using multiple linear regression analysis. This analysis allows to find the part of the dispersion (R^2) of the results of a political party that can be explained by these 18 parameters only factoring in the ones with a statistically significant correlation. This analysis also weighs in the collinearity of between these 18 factors and excludes it from the model.

After the initial analysis, the results of 6 political parties in the 8th Saeima elections were obtained, and a new model was tested which used 18 initial agricultural parameters and the proportion of Latvians in rural parishes from the 2000 census data (Centrālā Statistikas Pārvalde, 2010). Therefore, this analysis allowed to test whether the previously obtained results showed a believable and statistically significant relation between election results and agricultural factors (this model excludes collinearity with the ethnic factor) or this relationship just explains that both the election results and agricultural factors are related to the ethnic composition of Latvia.

Results and Discussion

The obtained results showed that 18 agricultural parameters have a varying degree of influence on the

Table 1

Summary of multiple linear regression analysis results of political parties in the 8th Saeima elections

Analyzed parameter	Analyzed political party in 8th Saeima elections					
	TBLNNK	PCTVL	JL	TP	LPP	ZZS
average farm size (ha)			x			x
% of farms producing agricultural products		x	x	x		
% of farm owners with a higher education in agriculture			x		x	x
% of farm owners with a practical experience in agriculture		x	x			x
Average size of forest land (ha) in farms			x	x		
Meliorated farmland (ha) per 1 farm			x			
% of meadows from total used land		x				
% of pastures from total used land			x	x		
5 – 10 ha sized farm % of total used land		x	x	x	x	
50 – 100 ha sized farm % of total used land						
% of potatoes from total harvested land			x			
% of harvested land from total used land		x				
% of industrial plants from total harvested land			x			
Cattle per 1 farm						
Pigs per 1 farm						
Sheep per 1 farm		x	x	x		
Poultry per 1 farm			x			
Motor mowers per 1 farm	x	x	x	x	x	x
Total number of factors	**1**	**7**	**13**	**6**	**3**	**4**
Dispersion explained by the model (R^2)	4.1%	48.7%	53.0%	53.4%	17.5%	14.5%

results of political parties (Table 1). For example, TBLNNK election was not at all influenced by these factors and only showed a minor positive correlation between their election result and the usage of farming machinery (described with the number of motor mowers per 1 farm). From all political parties in the 8th Saeima, TBLNNK relationship with agricultural factors is the smallest, accounting only for 4.1% dispersion of their results.

For PCTVL, their election results were statistically significantly related to 7 of the analyzed parameters. The main factor that influenced their election results in 2002 was 5 – 10 ha sized farm percentage of total used land (Figure 1). This parameter explains the role of small farms in the rural parish and these kinds of farms have the highest role in Latgale electoral district. In Latgale 5 – 10 ha sized farms compose about 25% of total used land, which is more than 2 times larger than in the rest of rural Latvia. It also explains why the correlation for this parameter with PCTVL election results is positive because PCTVL had their largest support (more than 27%) in rural parishes in Latgale, at the same time they had less than 5% of the vote in the rest of rural Latvia. This linear regression with PCTVL alone is quite significant (R^2 = 36%).

JL election results in the 8th Saeima election had the largest number of agricultural parameters (13) with whom it had a statistically significant relationship, accounting for about 53% dispersion of their results. The main agricultural parameter that influenced JL election results is the same as PCTVL, 5 – 10 ha sized farm percentage of total used land, alone explaining more than 25% dispersion of the parties results. The main difference between JL and PCTVL election results lies in the fact that the JL correlation with this parameter is positive (JL had less than 10% of the vote in rural Latgale while 25% in the rest of rural parishes in Latvia). Most of the 13 agricultural parameters that influenced JL election results are similar in a way that they have a contrast in their values between Latgale and the rest of Latvia.

In comparison, TP election result is only significantly influenced by 6 agricultural factors, while the multiple regression model is almost equally strong as for JL, explaining 53.4% dispersion of the results. The main parameter that influences TP election results also is the same as for JL and PCTVL. The main difference for JL in the number of significant factors can perhaps be explained by the fact that even though the 'Latgale and the rest of Latvia' contrast is strong for TP 8th Saeima election results, they also have a noticeable variation of their results outside Latgale (which is not that noticeable in many analyzed agricultural parameters), obtaining their highest result in Zemgale electoral district.

LPP and ZZS 8th Saeima election results were to a lesser extent influenced by the analyzed agricultural factors explaining 17.5% dispersion of LPP election results and 14.5% of ZZS dispersion. For LPP the main parameter that influenced their results also were 5 – 10 ha sized farm % of total used land showing a small but statistically significant positive correlation. ZZS election result was mostly influenced by parameter describing average farm size (ha) showing a small positive correlation (R^2 =10%). This relation can be explained with higher ZZS election results in Kurzeme rural parishes (especially around Ventspils city) where this political party had their strongest election results. This factor also increased its role in later elections (in 2010 and 2011) when their election result around Ventspils area was even higher. The reason why ZZS and LPP are less influenced by these agricultural factors than JL, TP and PCTVL is probably because ZZS and LPP have a much smaller contrast in their election results between Latgale and the rest of Latvia. For example, ZZS managed to gain 16% of the vote in rural Latgale which is only a fraction smaller than their result in the rest of rural Latvia (17.5%).

The obtained results for analyzed parties (Table 1.) show that the highest influence on election results have those parameters that are describing the farm structure in a parish, not the ones describing the agricultural specialization in the farms. These highly influential parameters are more related to the wealth and standard of living in a parish. That can be described with parameters related to intensity of farm machinery or role of small (5 – 10 ha) farms. It turns out that the type of crop grown in the farms (agricultural specialization) or the type of livestock mostly used in farms has almost no noticeable effect on election results.

It must be noted that this multiple regression analysis for agricultural parameters also produces largely similar results if used on political party results in recent elections. Election results of "Harmony Centre" in the 9th Saeima election are equally influenced by these 18 agricultural parameters, as are PCTVL in the 8th Saeima elections, explaining 44% of dispersion and having almost the same parameters with a statistically significant correlation. The same is true for other analyzed political parties and also for the 10th and 11th Saeima elections. The reason this model works for latter elections is probably related to the fact that political parties largely keep their voters and spatial characteristics of their results in many elections with a relatively slow change over time. The 'rural Latgale and rest of rural Latvia' contrast is also present in other elections. Of course, it would be more relevant to compare the 10th and 11th Saeima elections with the 2010 Census of Agriculture,

but these results have not been obtained in the parish level of detail.

If the parameters in multiple linear regression model also include the percentage of Latvians in 2000 then the obtained results have a completely different meaning. For all political parties in the 8th Saeima elections, the explained dispersion increased, but it was because of the inclusion of proportion of Latvians in the model. Meanwhile, the role of agricultural factors in the model was greatly reduced. For example, 18 analyzed agricultural factors account for 49% of the PCTVL 8th Saeima election results and with the proportion of Latvians (Figure 2.) included in the model this new model now explained almost 81% dispersion of the party results. But in the new model, the proportion of Latvians alone explained 74% of the PCTVL election results which left only 7% of the explained dispersion for the analyzed agricultural factors. Smaller but also similar differences between these models are true for the rest of analyzed 8th Saeima political parties.

This means that ethnic factor not only has a large correlation with the election results but also with many agricultural parameters. Therefore, most of the relation election results have to agricultural parameters is indirect. The reason why a proportion of Latvians has a relation to certain agricultural parameters is probably caused by historical development of land use characteristics in Latvia. It also must be noted that even though agricultural factors are related to election results to a much lesser extent than the first model showed, it still is a statistically significant factor that has an influence over the election results and it must be included into a more detailed quantitative about election results.

The most important factor, that has a relation to the election results, is the parameter describing the role of 5 – 10 ha sized farms (Figure 1). If compared to the proportion of Latvians in 2000, the correlation between them is relatively strong, explaining a statistically significant part of the dispersion. The main similarities are in the 'Latgale and the rest of Latvia' contrast that persists in both parameters. This contrast is so severe that even though these parameters have a different composition in the rest of Latvia, this contrast makes their correlation with each other strong.

By conducting cartographic analysis of the Irish parliamentary election of 2002, a significant difference was found in the election activity between urban and rural areas, with city dwellers showing a lower activity in the parliamentary election. It has been explained both by stronger sense of community in rural populations, and by the high proportion of

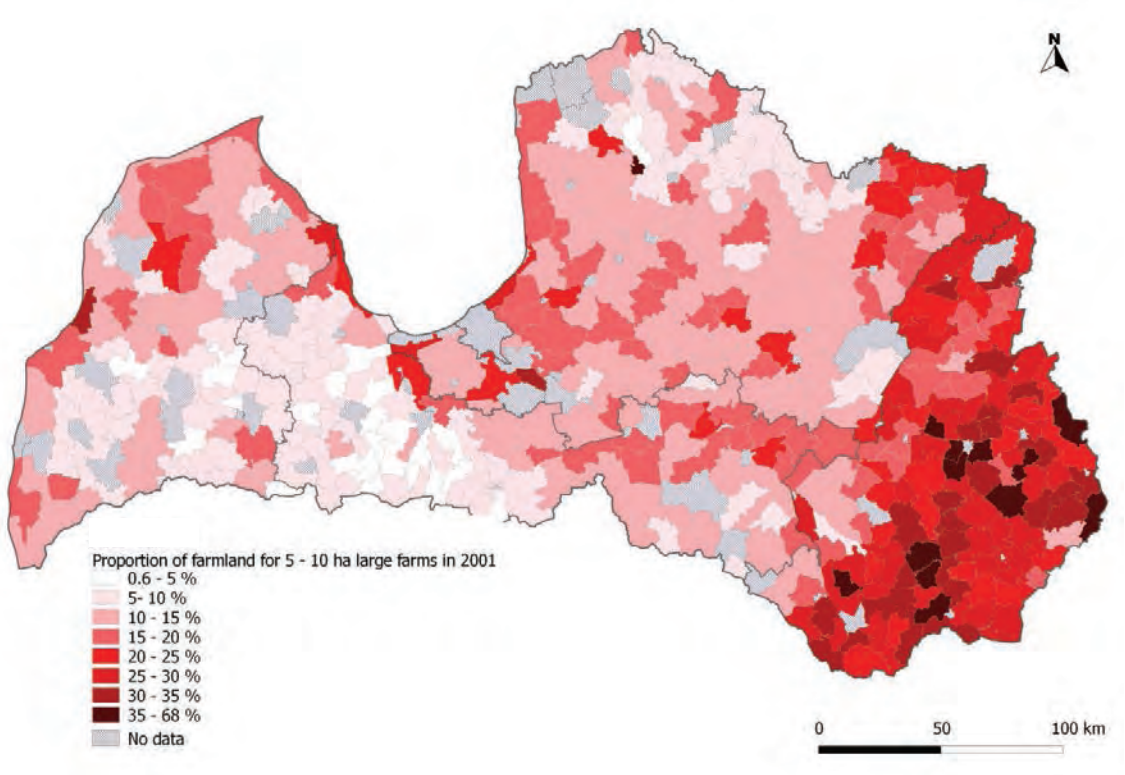

Figure 1. 5 – 10 ha sized farm % of total used land.

Data: Central Statistics Bureau of Latvia

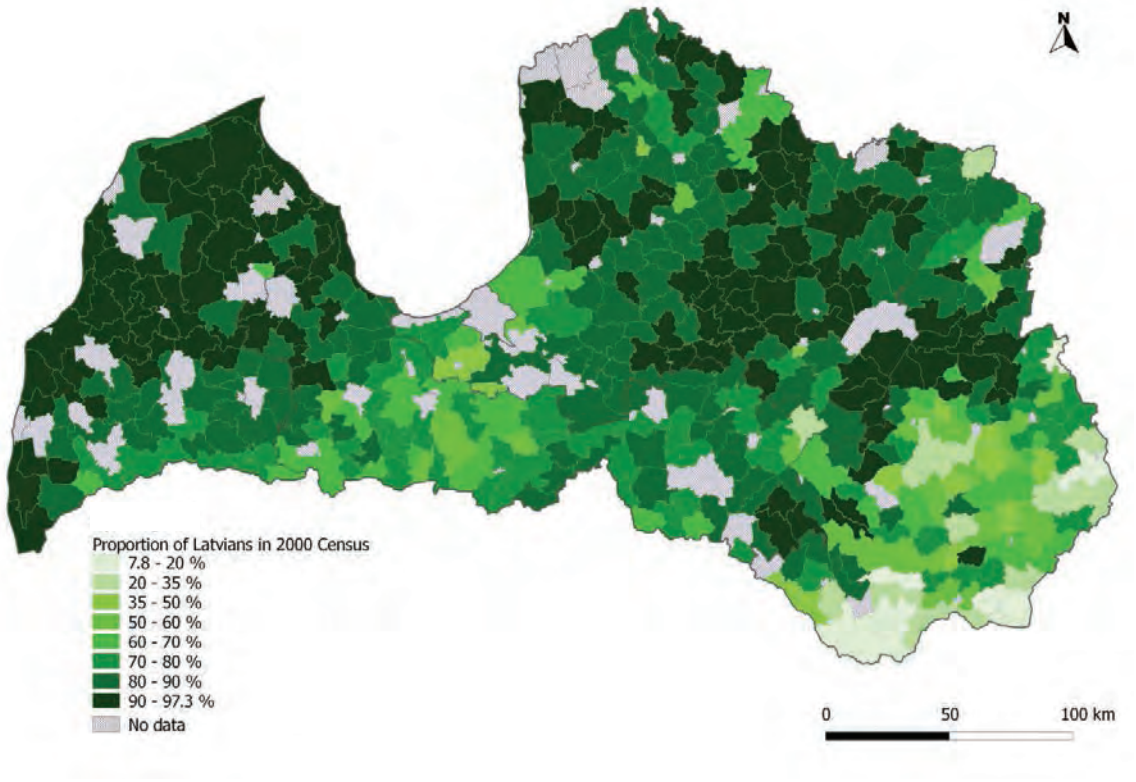

Figure 2. Proportion of Latvians in 2000 census.

Data: Central Statistics Bureau of Latvia

senior citizens in the rural regions of Ireland, with this group of population being more politically-active (Kavanagh et al., 2004).

In the example of Italian election results, a major role in their geographical dispersion is played by the uneven spatial distribution of various developmental factors on a regional level in the country. The results of the Italian Christian Democracy party in the period from 1953 to 1987 show that the standard deviation of the party's results is much greater between regions on a countrywide scale than between provinces on a regional scale (Agnew, 1996). However, the author of this study notes at the end of the article that there are several limitations in applying the neighborhood effect to interpretation of the results.

Geographical research with the application of scalar field properties is limited by several factors. One of them is the modifiable areal unit problem (MAUP). Gehlke and Biehl (1934) discovered that the correlation coefficient is sensitive to scale changes of the examined territories. Openshaw and Taylor (1979) began using the term MAUP for the investigation and assessment of this problem. The focus has largely been placed on research of how spatial models are affected by scale changes (Fotheringham and Wong, 1991; Briant et al., 2010, etc.).

This work is a part of electoral geography, but the geographical factors which have an impact on election results are different between countries. In case of Turkey parliamentary elections, it was found that four major divisions are shaping the electoral geography: religion, ethnicity, regional economic prosperity, and previous state association (West, 2005). In Latvia, out of three possible levels on which electoral geography can be researched – local, regional, and national (Krampe, 2005) – election results have most often been examined at the national (electoral district) level. Electoral geography has been relatively little researched at the academic level in Latvia, with studies that deal with the spatial distribution of parliamentary election results giving it very little attention (How Democratic Is Latvia, 2005).

Studies of electoral geography have also examined the behavior of specific voter groups in relation to geographical factors, with groups being formed by ethnicity, race, income level, etc. (Groffman and Handley, 1989; McLaughlin, 2008). The influence of the ethnic composition on parliamentary election results in Latvia has already been discussed in previous publications of the authors (Paiders, 2012; Paiders and Paiders, 2011). Often, studies in the field of electoral geography focus specifically on

examining the electorate of radical political forces, including research of its spatial dispersion (Alexseev, 2006; Stefanova, 2009; O'Loughlin et al., 1994). When evaluating the results of other countries, the differences in the political systems of these countries in comparison to Latvia must be taken into account.

Conclusions

Multiple linear regression analysis allows to measure the impact on election results for many potentially influential parameters allow to create a model that also takes into account the collinearity of these analyzed parameters; and the relationship and collinearity between many parameters from the agricultural census is too large not be noticed.

18 agricultural parameters that were used in the multiple regression model allowed to explain a considerable part of the dispersion of the 8th Saeima election results. For TBLNNK, LPP and ZZS their relation to the analyzed parameters in the model can be considered small, accounting for less than 20 % of dispersion of their results, while for PCTVL, JL and TP the model was more relevant, accounting for more than 48% of their results.

The main reason why certain political party results in the 8th Saeima had more significant results in their relation to the analyzed agricultural parameters are perhaps connected with the gap in the election results between rural Latgale and the rest of rural Latvia. If this gap is large then the connection with the agricultural parameters is strong but if the election results are more equally distributed amongst the electoral districts then these 18 parameters have a small influence.

The 2001 agricultural census data can be used to analyze later elections (even in 2010 and 2011) mostly because the political parties tend to keep their voters and spatial characteristics in many elections. The importance of agricultural factors is greatly reduced if the proportion of Latvians is included in the model. For PCTVL in 2002, agricultural factors together with the ethnic factor explained almost 81% dispersion of the party results. But in the new model the proportion of Latvians alone accounted for 74% of the PCTVL election results which left only 7% of dispersion explained by agricultural factors. Before the ethnic factor was included in the parameters, agricultural factors accounted for 48% on PCTVL results. For other political parties this tendency is also similar.

References

1. Agnew J. (1996) Mapping politics: how context counts in electoral geography. Political Geography, 15 (2), pp. 129 – 146.
2. Alexseev M. (2006) Ballot-Box Vigilantism. Ethnic Population Shifts and Xenophobic Voting in Post-Soviet Russia. *Political Behavior*. 28 (3), pp. 211 – 240.
3. Briant A., Combes P.P., Lafourcade M. (2010) Dots to boxes: Do the size and shape of spatial units jeopardize economic geography estimations? Journal of Urban Economics Vol 67, (3), May 2010, pp. 287 – 302.
4. Centrālā Statistikas Pārvalde (2003) Latvijas 2001. gada lauksaimniecības skaitīšanas rezultāti. (Central Statistics Bureau of Latvia, Results of the 2001 Agricultural Census in Latvia). Riga (in Latvian).
5. Centrālā Statistikas Pārvalde (2010) 2000. gada tautas skaitīšana. (Central Statistics Bureau of Latvia, 2000 Population Census). Available at: http://www.csb.gov.lv/dati/2000gada-tautas-skaitisana-28291.html, 23 January 2014. (in Latvian).
6. Centrālā vēlēšanu komisija (2011) Saeimas vēlēšanas (Central Election Commission, Saeima elections). Available at: http://web.cvk.lv/pub/public/27427.html, 27 October 2011. (in Latvian).
7. Fotheringham A.S., Wong D.W.S. (1991) The modifiable areal unit problem in multivariate statistical analysis. Environment and Planning A. Vol. 23(7) pp. 1025 – 1044.
8. Grofman B., Handley L. (1989) Black Representation: Making Sense of Electoral Geography at Different Levels of Government. Legislative Studies Quarterly, 14 (2), pp. 265 – 279.
9. Stratēģiskās analīzes komisija (How Democratic is Latvia: Audit of Democracy). (2005) LU Akadēmiskais apgāds, Rīga, 309 lpp. (in Latvian).
10. Kavanagh A., Mills G., Sinnott R. (2004) The geography of Irish voter turnout: A case study of the 2002 General Election. Irish Geography, 37 (2), pp. 177 – 186.
11. Krampe A. (2005) Latvijas elektorālie procesi politiskajā ģeogrāfijā (Electoral proceses in political Geography in Latvia). Ģeogrāfija. Ģeoloģija. Vides zinātne: Referātu tēzes, Latvijas Universitāte, Rīga, 57 – 58. lpp. (in Latvian).
12. McLaughlin E. (2009) Racial, Ethnic or Rational Voters. Splitting Tickets in South Africa. Politikon. 35 (1), pp. 23 – 41.
13. Paiders J., Paiders J. (2011) Nacionālā sastāva ietekme uz 10. saeimas vēlēšanu rezultātu ģeogrāfisko sadalījumu (Ethnic composition influence on 10th Saeima Election results). *Ģeogrāfija. Ģeoloģija. Vides zinātne: Referātu tēzes*, Latvijas Universitāte, Rīga, 180 – 182. lpp. (in Latvian).

14. Paiders J., Paiders J. (2013) EU Border Proximity Effect On Political Choice In Parliamentary Election Of Latvia. *Regional formation and development studies.* 1 (9) Klaipeda: Faculty of Social Sciences Klaipėda University. pp. 114 – 123.
15. O'Loughlin J., Flint C., Anselin L. (1994) The Geography of the Nazi Vote: Context, Confession and Class in the Reichstag Election of 1930. Annals of the Association of American Geographers, 84 (3), pp. 351 – 380.
16. Stefanova B. (2009) Ethnic nationalism, social structure, and political agency: explaining electoral support for the radical right in Bulgaria. Ethnic and Racial Studies. 32 (9) pp. 1534 – 1556.
17. West J.W. (2005) Regional cleavages in Turkish politics: An electoral geography of the 1999 and 2002 national elections Political Geography Volume 24, Issue 4, pp. 499 – 523.

STAFF MOTIVATION IN MUNICIPAL ADMINISTRATION: EXAMPLE OF R. HACKMAN's AND G. OLDHAM's WORK CHARACTERISTICS MODEL

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Abstract
This article analyses the elements of R. Hackman's and G. Oldman's work characteristics model: the essential work characteristics, critical psychological states, as well as personal and activity results. Research aim - to offer municipal administrative staff innovative elements of the motivation system.
The elements of employee motivation are linked with certain work characteristics, distinguishing specific features of the work process that would meet the needs of workers such as the use of self-expression and potential opportunities, ensuring satisfaction with the content of work, independence and recognition.
Before suggesting innovative motivation system elements, the factors and motivation measures that most influence municipal administrative staff of Raseiniai, Joniškis, Pakruojis, Akmenė had been found out. Essential elements of work characteristics model (essential work characteristics, psychological states and personal and activity results) among the employees were identified. It presents the characteristics of innovative motivation system elements of municipal administrative staff. Main analysis methods were used: analysis of documents, quantitative research – survey, comparative analyses, methods of statistical and cluster analysis.
Key words: motivation, systems, work characteristics model.

Introduction

The issue of staff motivation is relevant not only to private but also to public sector. However, it should be noted that public institutions do not pay enough attention to staff motivation and the development and improvement of the motivation system. There is insufficient knowledge about motivation and experience of how to implement this.

Public sector workers, who are reluctant and passive in carrying out their duties, are often criticized. One of the weaknesses of the public sector is that it is governed by various laws that restrict an employee's activities and prevents the creative potential. Insufficient and inflexible work motivation of the public sector employees interferes with the organisation's effectiveness, efficiency, and quality (Donelson and Park 2009; Locke, 2004; Clary, 1996). To identify appropriate motivating tools and methods is not easy, but it is necessary to look for measures to motivate employees of public institutions through identifying their wishes, needs, and motives which change depending on the individual's operational objectives, aims, and time.

Research object – the elements of work characteristics model of municipal administrative staff.

Research aim - to offer municipal administrative staff innovative elements of the motivation system.

Research objectives:

1. To analyse the elements of work characteristics model of the municipal administrative staff.
2. To define the significance of work characteristics model elements in municipal administrative staff motivation.

Materials and Methods

Theoretical Analysis of Work Characteristics Model Elements. Definitions of motivation emphasize certain processes that cause and direct the employee to achieve a certain goal and identify the dominant aspects of: what triggers human behaviour, i.e. incentivises to behave in one way or another; what directs this behaviour and incentive for a particular purpose; how this behaviour is supported.

The elements of the motivation process in this article are analysed on the basis of Hackman's and Oldham's (2008) work characteristics model presented in Figure 1.

The process of performance motivation in the model is characterized by 3 components: essential work characteristics, critical psychological states as well as personal and activity results.

Essential work characteristics include the following: *diversity of skills* – a parameter which defines how many different types of activities the task includes and how many different skills and abilities the individual performing certain tasks has to apply. This article analyses the intrapersonal, interpersonal, communication and activity skills; *task identity, significance* is about how much work is required to complete the task and a clearly defined part of it fully, and how significant an impact the work has on other people's lives or work. There are many tasks performed in the organisation at the same time, therefore, it is important to group them and identify their significance. Tasks are usually grouped according to the level of abstraction, time frame, the level of hierarchy, significance, and sequence (Bagdonas and Bagdonienė, 2000); *autonomy:* how much freedom,

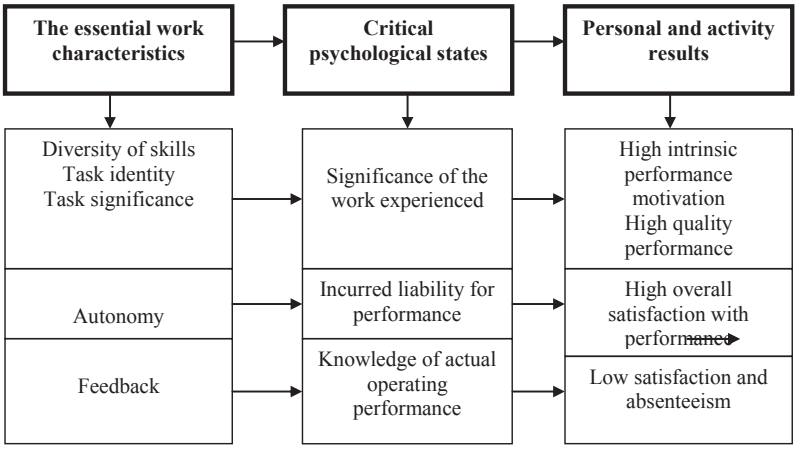

Figure 1. Work Characteristics Model (Hackman and Oldham, 2008).

independence, and freedom of decision work gives people so that they are able to plan and decide themselves what procedures are necessary to do this work. Autonomy determines to what extent employees are free and independent in carrying out their work, such as deciding on the sequence of performing the tasks and selecting the ways of working. Sometimes, however, an organisation takes some of autonomy of individual's decision and replaces it with the decision-making process of the organisation. The article focuses on employee autonomy enhancement techniques: flexible working hours and work enrichment; *feedback*: how much of direct and clear information about an employee's operational efficiency is provided by activities needed to carry out the work. Feedback is an important aspect of work, encountered in different situations, and that helps to form the employee's personal image and evaluate the behavioural actions. Formal feedback systems rarely meet the needs of the organisation or the employee.

Feedback, associated with the work, is essential if the work brings intrinsic rewards such as a sense of success or, if necessary, in-service training.

Personal and activity results include the following: *high intrinsic performance motivation.* People's working behaviour is driven by various interrelated internal and external forces. The internal driving forces are the needs, interests, goals, values, orientation of values, ideals, and motives. All of them constitute the structure of the motivation process of complex social work activities. The essence of the motivation process of work activities is the formation of those driving forces of work behaviour; *high-quality performance*. Motivation will not be high in weak connection between effort and performance (capacity/quality). The key factor in enhancing motivation is an anticipated constructive evaluation of a manager (work performance evaluation), thus, it can be said that performance indicators (capacity/quality) depend not only on the effort, but also on objective factors; *high overall satisfaction with performance*. Researchers of employee behaviour have for a long time been interested in the factors affecting an individual's motivation to work. Studies have shown that in most cases the behaviour is often determined by external and internal factors. Internal motivating factors are related to the employee's personal characteristics. These factors are very difficult or simply impossible for managers to control. Internal factors may include education, work experience, and so on. The external factors may include wages, work content and the nature of it, career opportunities, manager competence and leadership style, relationships with co-workers, and working conditions; *low satisfaction and absenteeism*.

Job satisfaction and employee turnover. Studies carried out by R. Steers (2002), K. Dawis (1995), Grant (2008) found that higher job satisfaction is associated with lower employee turnover. Conversely, those who feel lower satisfaction are more likely to leave their workplaces. Increased work experience in one organisation reduces dissatisfaction with work among working men. In this case, there emerges another factor - the commitment to the organisation, which plays an important role in the relationship between job satisfaction and voluntary employee turnover.

Job satisfaction and absenteeism. Studies found (N. Bluendorn 1992) that there is an inverse relationship between job satisfaction and absenteeism. When the level of job satisfaction is low, absenteeism increases, when people are satisfied with the job, there is little absenteeism.

In summary, it can be said that the elements of employee motivation are linked with certain work characteristics, distinguishing specific features of the work process that would meet the needs of workers

such as the use of self-expression and potential opportunities, ensuring satisfaction with the content of work, independence, and recognition.

Research methods. Analysis of documents, quantitative research – survey, comparative analyses, methods of statistical and cluster analysis.

Results and Discussion

Empirical Analysis of Work Characteristics Model Elements Based on Municipal Administrative Staff Model. In order to determine which essential characteristics, critical psychological states, personal and activity results motivate the municipal administrative staff the most, a study was conducted. The study involved 143 respondents from Raseiniai, Joniškis, Pakruojis, Akmenė district municipalities.

Study analysis of essential work characteristics. When examining the significance of the skills, the respondents' answers are presented in importance indices (IND) for each skill area, after having systematised the response data and calculating the average.

It was found that the area of activity and communication skills are the most significant for the respondents and are most motivating to work (IND = 1.43). It can be concluded that managers should focus on developing employee performance and cooperation skills. This could be done through developing specialized training programmes which would include the modules on the characteristics of the organisation of activities, the creation of a pleasant work environment, the evaluation of activity results.

The most common task of the public sector employee is to be responsible for a state-owned or administered part of activities (e.g. healthcare, education, construction, social assistance, small business registration, taxation, the environment, etc.). A public sector employee is an employee of a public institution (ministry, district, city and municipal authorities, labour exchange, school boards, etc.) of the state or region, municipality or other level of administrative division, therefore, the work content and the quality of performance should be the essential criteria for the evaluation of the work carried out by the aforementioned employees (granting adequate wages, assessing qualifications or carrying out certification).

During the study, respondents were asked about the ways the tasks are performed, their structure and significance. Most frequently, the respondents carry out the assigned tasks individually and to the end, or perform 90 percent of the tasks themselves and leaving 10 percent to their colleagues or managers.

General conclusions about the performance of the tasks showed that the tasks in municipal administration are allocated on the basis of the division of labour and hierarchical structure, which provides each employee's personal responsibility for the work results. These statements were confirmed by respondents' responses about work autonomy. 55 percent of respondents said that at work dominates personal responsibility for everyone works separately and independently.

When analyzing the task diversity and specificity, 57 percent of respondents replied that the task structure is varied – at work they perform both monotonous and innovative tasks. The analysis of the structure of the task showed that the key evaluation criterion is the period during which it is necessary to perform the task. The response was indicated by 84 percent of respondents; customer needs and position (hierarchy level) were identified as the second and third priorities respectively, sharing 69 percent each; professional experience was chosen by 64 percent of study participants.

What municipal administrative staff find most relevant is the significance of work and performance objectives. Especially significant is the joint preparation of departments' goals and mission. Then the employees can see how the objectives of their departments are related to the overall goals of the organisation.

96 percent of respondents said the main reason of the task was an opportunity for continuous professional development; the second was the ability to get a good salary (79 percent), and the third to independently manage their time (43 percent). It can be stated that the municipal administrative staff link the development of professional skills (professional development) to wage increases. The scientific literature suggests that one of the measures of motivation in municipalities is career advancement, i.e. the higher qualification class is given, but not all municipal employees are career civil servants (this option is not available to those working under contracts), and on the qualification class depend the main wage size, premiums, etc.

The analysis of the effectiveness of feedback showed that efficiency is determined by a specific and clear communication of information (88 percent); the competence of persons communicating the information (64 percent); the competence of employees (respondents) to communicate information to others (60 percent); timely information update (57 percent).

In order to determine the significance of the essential work characteristics (the respondents had to rank them in order of importance: *1 – the most significant, 5 - least significant*), the following results were obtained: the respondents identified skills application (IND = 1.74) and task significance (IND = 2.36) as key characteristics at work, while less attention was given to work autonomy (IND = 3.28), task identity (IND = 3.45), and feedback (IND = 4.17).

In summary, it can be said that the employees whose tasks require different types of skills, task significance and identity, hold their work as very significant. A high level of autonomy makes employees more responsible and promotes accountability for their actions. Feedback gives them a useful understanding of their specific roles and functions. The more of these characteristics work has, the greater the chance that the person who does the work will be more motivated and satisfied.

Study analysis of critical psychological states. Despite the importance of work that will be done or what personal responsibility for the work activity will be taken, if an employee can not define whether the activity was effective or not, it is impossible to experience positive and negative emotions that are essential components of internal motivation (Marcinkevičiūtė, 2010).

When examining the significance of municipal administrative staff, the following tendencies have been determined:

1) 58 percent of respondents related the significance of work to the assistance when solving clients' problems;
2) 30 percent of respondents related the significance of work to the assistance when solving colleagues' job-related problems;
3) 18 percent of respondents related the significance of work to the assistance when solving managers' job-related problems;
4) 13 percent of respondents related the significance of work to the assistance when solving job-related problems of the organisation.

The employee aims at using the acquired qualification, capabilities, knowledge, and experience at work and the more he/she succeeds, the higher level of satisfaction, as well as motivation, is achieved. When evaluating the responsibility for work results experienced by municipal administrative staff, the mentioned element is significant for 47 percent of respondents. The experienced responsibility they related to the activity results of the organisation.

The awareness of concrete work activity results is one more critical psychological state that has impact on work motivation. When examining this psychological state, it has been identified that the evaluation concrete work results is obtained from the positive responses of the clients (56 percent) and information of the managers (35 percent). The information about work results, as well as feedback, provides employees with the intense awareness of their specific role and functions.

In order to find out the significance of critical psychological states (the respondents had to rate them in order of importance: the most significant – taken responsibility for work results (IND = 1.75), next – experienced work significance (IND = 1.89), and the least significant – the awareness of concrete work activity results (IND = 2.36).

To sum up, it can be stated that almost all critical psychological states that belong to internal motivation are quite significant for the respondents.

Study analysis of a person and activity results. This part of the study involves the analysis of the main factors that determine internal work motivation, the most significant motives and existing motivation measures in municipalities. The study also includes the measures of motivation requested by municipal staff.

As the data show, the key factor of motivation is willingness to do this job (83 percent), work content (75 percent), aspiration for professionalism and mastery (73 percent) and better material welfare. These aspects can be treated as the most significant factors of internal motivation by reason of which the employees work at municipalities.

When answering the question if there is quality control at work, respondents' answers were distributed into two answer variants: that the quality of work is their own responsibility (57 percent of respondents) and that the quality is checked once or twice a year (34 percent of respondents).

Presumably, effective system of administration control allows employees evaluate and improve their work. This stimulates greater devotion and enhances the satisfaction of their work. One of the up-to-date tendencies of administrative control evolution is the control performed by the managers that should be exchanged by the self-control of employees. The manager only has to provide them with the assistance and support when it is needed.

It is important to know what respondents evaluate most at work. The given answers had to be ranked: the most significant factor was high quality of work performance (IND = 1.64) and overall job satisfaction and higher internal activity motivation are almost equal in conformity with significance.

As there is not much difference in coefficients of efficiency, the conclusion can be drawn that respondents evaluate all factors related to activity results at work.

Improvement of Motivation System of Municipal Administrative Staff. In both theoretical literature and practical studies, different approaches to motivation systems are being analyzed. However, many of them are different not only in their content but also in their structure.

According to the data of theoretical analysis, existing elements of motivation system of municipal administrative staff are presented in Table 1.

Table 1

Motivation System Elements in Municipal Administrative Staff (according to the collective contracts of Raseniai, Joniškis, Pakruojis and Akmenė districts)

Motivation system elements	Basic measures	Acts of law regulating motivation measures
Economic material-monetary motivation measures	Wages Bonuses Extra pay Promotion and awards Compensation	the Resolution of the Government of the Republic of Lithuania No 511, 8 July 2003; the Civil Service Law
Economic material – non-monetary motivation measures	Free use of the organisation car Mobile phone Equipment and devices necessary for work	the Decision of Municipal Council; Administrative Director's Decree
Social security	Annual and training leave Unpaid leave Leave for qualification improvement Additional annual leave Purposive leave Free time Other guaranties	The Resolution of the Government of the Republic of Lithuania No 511, 8 July 2003; the Civil Service Law; the Decision of Municipal Council; Administrative Director's Order
Consolidation of the status	Evaluation of the activity Employees' training	the Civil Service Law; annual training plan for civil servants and employees

Table 2

Characteristic of Innovative Motivation System Elements of Municipal Administrative Staff

Innovative motivation system elements	Major motivation system goals	Application of measures
Essential work characteristics	Stimulation of activity and cooperation skills	Managers mainly should focus on employees' stimulation of activity and cooperation skills. This could be done by creating specialised training programmes that would involve modules on activity organisation, creation of pleasant working atmosphere, peculiarities of activity results evaluation
	Precise definition of tasks and their significance	The tasks should be allocated according to work division and hierarchical structure that determines personal responsibility for the results of every employee. The designation of tasks and their performance should be related to pay system
	Enhancement of autonomy	The employees should be provided with the opportunity to choose the sequence of tasks and methods of their performance
	Formation of feedback	The information that is provided 'top-down' and 'bottom-up' should be elaborated according to the position at work, avoiding information mediators
Psychological states	Experience of work significance	Work significance experienced through self-awareness by performing tasks for organisation. General arrangement of goals of departments and organisation mission should benefit employees to understand their particularity of work when dealing with various tasks
	Cultivation of responsibility	Social responsibility as well as personal should be related to activity results of an organisation and its cultivation should be immediately related to well-timed and qualified performance of the tasks set up by the organisation
	Awareness of concrete work activity results	Employing principles of feedback and informing employees about activity results, managers would form growing awareness about specific role and their functions in the municipality. The possibilities to apply information measures should be developed by using information technologies
Personal and activity results	Formation of internal motivation	Managers should use appropriate management instruments that could inspire internal motivation of employees (self-motivation) to achieve better results. Self-assessment would stimulate and determine employees' behaviour and it would influence not only actions but also goals and strategic objectives
	Broadening the types of motives	The use of specific types of motives for employees would secure the process of work activeness stimulation in municipalities
	Enhancement of work quality	To stimulate employees' self-control, by determining their professional advantages, and, through specifically formulated tasks, provide employees the opportunity work in the fields that would lead to maximum results

Before suggesting innovative motivation system elements, the factors and motivation measures that most influence municipal administrative staff had been found out. Essential elements of work characteristics model (essential work characteristics, psychological states and personal and activity results) among the employees were identified.

Based on theoretical and practical studies, the characteristic of innovative motivation system elements of municipal administrative staff was prepared (Table 2).

In order to perform tasks professionally, municipal staff should develop existing competence in various fields and acquire new competence, think rationally and critically, penetrate the problems and be able to solve them, know how to learn, and improve their managerial excellence.

Conclusions

1. Employees' motivation elements could be related to certain work characteristics, distinguishing specific features of the process that would meet employees' needs such as self-expression and use of potential possibilities, ensuring satisfaction of work content, independence and recognition.

2. The main characteristics at work were identified as follows: skills application (IND = 1.74) and task significance (IND = 2.36), less attention was given to work autonomy (IND = 3.28), task identity (IND = 3.45), and feedback (IND = 4.17).

3. The essential critical psychological states were named as follows: responsibility for work results (IND = 1.75), work significance (IND = 1.89), and the awareness of concrete work activity results (IND = 2.36).

4. In the study on personal and activity results, the emphasis was laid on high quality of work (IND = 1.64), while general job satisfaction and high internal motivation were divided evenly according to their significance (IND = 2.08 and IND = 2.28).

5. In order to create rational staff motivation systems, there must be certain logical analysis and consistency, i.e. the preparatory work must be done: to evaluate existing state of staff motivation and motives and determine elements of study instruments.

References

1. Bagdonas E., Bagdonienė L. (2000) Administravimo principai (Principles of administration). Kaunas: Technology, pp. 10 – 14. (in Lithuanian).
2. Bluendorn N. (1992) Motivation and Leadership. Pittsburg: University of Pittsburg Press, pp. 54 – 56.
3. Clary E., Snyder M., Stukas A. (1996) Volunteers' Motivations: Findings from a National Survey. *Nonprofit and Voluntary Sector Quarterly*, 25(4), pp. 485 – 505.
4. Dėl biudžetinių įstaigų ir organizacijų darbuotojų darbo apmokėjimo tvarkos tobulinimo: Lietuvos Respublikos Vyriausybės nutarimas (Concerning salaries of personnel development in budgetary institutions and organizations in the Republic of Lithuania. Lithuania Government Resolution) (1993) July 8 d. Nr. 511. *Official gazette* (*Valstybės žinios),* Nr. 28-655. pp. 32 – 45. (in Lithuanian).
5. Dėl kai kurių kategorijų darbuotojų, turinčių teisę į kasmetines pailgintas atostogas, sąrašo ir šių atostogų trukmės patvirtinimo: Lietuvos Respublikos Vyriausybės nutarimas (Concerning some categories of employees entitled to annual leave and the list of holidays approval: Lithuania Government Resolution) (2003) July 18 d. Nr. 941*, Official gazette* (*Valstybės žinios),* Nr. 73 – 3375. pp. 25 – 28. (in Lithuanian).
6. Dėl valstybės tarnautojų ir darbuotojų, gaunančių darbo užmokestį iš Lietuvos respublikos valstybės biudžeto, savivaldybių biudžetų ir valstybės pinigų fondų, darbo užmokesčio fondo apskaičiavimo metodikos patvirtinimo. Lietuvos Respublikos Vyriausybės nutarimas (Concerning civil servants and employees who receive a salary from the state budget of the Republic of Lithuania, municipal budgets and public funds, payroll calculation methodology in approval. Lithuanian Government Resolution) (2003) April 3 d. Nr. 280. *Official gazette* (*Valstybės žinios),* Nr. 24 – 992. (in Lithuanian).
7. Dawis K., Gleen J. (1995) Human Behavior at work: Organizational Behavior. New York: McGraw- Hill Book Company, pp. 23 – 43.
8. Donelson A. (2009) Intrinsic Motivation. London: Kogan Page, pp.15 – 23.
9. Hackman R., Oldham G. (2008) Work Redisign. Reading: Addison-Wesley, pp. 45 – 50.
10. Grant R. (2008) Contemporary strategy analysis. Malden: Blackwell publishing, pp. 56 – 62.
11. Locke E. (2004) Psichological needs and the facilitation of integrative process. *Journal of Pesonality*, 63, pp. 397 – 427.
12. Marcinkevičiūtė L. (2010) Darbuotojų motyvavimo modeliai: teoriniai ir praktiniai aspektai (Employee motivation models: theoretical and practical aspects). Monograph: Kaunas:Lithuanian Agriculture University, pp. 47 – 56. (in Lithuanian).
13. Park M., Chu Y., Lee H. (2009) Evaluation Methdots for Construction Projects. *Journal of Civil Engineering and Management*, 15 (4), pp. 349 – 359.
14. Steers R. (2002) People in Organizations. New York: McGraw Hill, pp. 65 – 68.

RELATIONSHIP BETWEEN CONSULTANTS AND CLIENTS IN KAUNAS LAW FIRMS

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Abstract
Relationship between clients and consultants reveals and develops during the process of communication, because then not only do people interact, but they also get to know each other. Consultants and clients influence each other by sharing information, emotions and feelings. By influencing each other, they change attitudes, feelings and behaviour in the process of consultation. These relations influence the moral state of both consultants and clients, and while interacting, they influence efficiency of consultant activity as well.
This paper analyses relationship between consultants and clients, as well as defines both factual and interpersonal aspects of communication.
Key words: consultation, client, consultant, relationship between clients and consultants. JEL codes: M120.

Introduction

Consultation helps clients to analyse the situation, determine the problems and its possible solutions, increase and deepen knowledge, develop perceptiveness, organize and direct the knowledge to the right way, gain professional knowledge, take reasonable and responsible decisions. Not only has the content of the consultation to be qualified, but also the relationship between clients and consultants has to be appropriate. A consultant must be capable of understanding the client, perceiving his feelings and personal features. Customer complaints about the work of consultants cannot only affect the decision-making, but also have much influence on their relationship, whereas good client-consultant relationship and pleasing mutual interaction can definitely help to deepen knowledge and facilitate decision making.

From the managerial point of view, the interaction between consultants and clients is still in the stage of infancy. There is no clear definition of reasons and factors that determine the origination of certain consultant and client relationship.

The object of the research is the relationship between clients and consultants.

The aim of the research is to analyse the relationship between consultants and clients in law advisory firms and therefore to provide opportunities for the development of their relationship.

The objectives of the research are as follows:

1) to summarize the conception of consultant-client relationship;
2) to define factors determining the relationship between consultants and clients;
3) to assess the influence of the factors to the relationship of consultants and clients;
4) to investigate the relationship between consultants and clients in consultation companies;

Materials and Methods

Materials and methods of the research are as follows: in this paper, the analysis and synthesis of the scientific literature, comparative analysis, logical analysis, questionnaire, graphical method, statistical data analysis, method of summarizing were used. In this paper, scientific and practical material of national and foreign authors (Baršauskienė et al., 2006) and others) were analysed.

Results and Discussion

The essence of consulting is to give a person help, which is used to receive information, master new working methods or restructure the old ones, predict oncoming activities in order to receive more efficient results and other related objectives (Melnikas and Strazdas, 1998; Van Den Banas and Hawkinsas, 1999).

Relationship between clients and consultants reveals and develops during the process of communication when not only do people interact, but also get to know each other (Zelvys, 1995; Gayeski, 2000). When a person communicates, his aim is to understand the speaker and the problem in question; therefore, despite all the possible risks, he himself becomes more open for discussions. Only in such cases the communication gets meaningful (Fiske, 1998; Steele, 1999).

Communication is a multisided phenomenon. As a matter of fact, the communication is subdivided into several types, groups and aspects. First and foremost, two types of communication should be distinguished: communication with oneself and communication with others (mutual, interpersonal) (Kavalov, 1970; Kociunas, 1997). As Baršauskienė (1999; 2003) under the observations of other researchers states, terms “interaction” and “communication” can be used as synonyms. However, the term “communication” generally refers to the mechanism of the connection between subjects, its form, methods for transferring

information, channels and, thus, is quite used when analysing activity of an organisation (Strazdas, 1995).

Consultants and clients influence each other by sharing information, emotions and feelings (Block, 2000). As a matter of fact, it forms particularly diverse and complex consultant-client relations, which can be determined as the transfer and reception of information for finding the best possible solution, for influencing each other, changing attitudes, feelings and behaviour in the process of consultation. These relations influence the moral state of both consultants and clients when interacting as well as they influence efficiency of consultant activity (Adamoniene, 2006; Barvydiene, 2003).

The communication takes place in two levels:

1) content/business;
2) emotional/interpersonal (Van Den Ban, 1999).

Factors that have much influence on operational relations are estimated by the objectives of operational communication that Baršauskienė (1999) subdivides into four categories: finding out, information, convincing and retaining attention. In order to reach the before-mentioned objectives in the process of consulting, the main factors determining the operational communications are to be assessed (Chreptaviciene, 2005).

Interpersonal communication mostly refers to informal communication among people. It usually lasts for a longer or a shorter period of time and reflects the certain intellectual or emotional closeness of the communicating actors. Although it is not possible to draw a strict boundary between personal and operational communication, the exclusive features and goals of such communication lead to specific differences of these forms of communication (Savaneviciene, 2005). Above the four most important aspects of operational communication (to find out, i.e. to get additional information about the goods or services in question; to inform, i.e. to convey the positive, negative or neutral information; to convince the client that the decision is beneficial; and to manage keeping his attention) the human factor is also of a significant importance. Therefore, the development of interpersonal relationship requires attention to a number of factors which can direct this relationship to a positive or rather negative direction. There are three main factors determining the efficiency of business relationship, such as ethical behaviour, conflicts and communication skills (Bowman, 1987).

This empirical research analyses how the main factors influence the operational and interpersonal relations between consultants and clients.

The Results of the Empirical Research

The aim of the research is to assess the factors that mostly determine the relationship between consultants and clients, as well as the influence of such factors on operational and interpersonal relationship of both the consultants and clients.

The survey method for the research was chosen. The questionnaire was made under the information provided in the scientific literature. Two different questionnaires (forms) were used. One questionnaire was given to consultants and the other one was given to clients who used the service of consultants. Both groups of respondents had to evaluate the influence of the same factors to relationship in the scale of five (Likert scale). The research was performed by selecting consultants and their clients from three institutions that are as follows: *UAB Kauno teisinių paslaugų centras* (Centre of Legal Services in Kaunas), public institution *Teisinių paslaugų, audito ir ekspertizės centras* (PI Centre of Legal Services, Audit and Expertise) and *UAB Verslo teisės centras* (Business Law Centre). In total, the survey included 15 consultants and 85 clients, i.e. 6 consultants and 35 clients from *UAB Kauno teisinių paslaugų centras;* 5 consultants and 25 clients from *PI Teisinių paslaugų, audito ir ekspertizės centras*; as well as 4 consultants and 25 clients from *UAB Verslo teisės centras.*

Despite the fact that research represents only the relationship between consultants and their clients from the institutions that took part in this survey, the assumption can be applied to the tendencies dominating in all the companies providing consultation services.

The factors that influence the consultant-client relationship have been analysed pursuant to the classification of factors described in the scientific literature. In order to assess the influence of these factors to operational and interpersonal relationship between consultants and clients, the respondents (consultants and their clients) were asked to classify the importance of each and every factor in the scale of five. The relevance of one factor is described by several variables. Afterwards, scores of each variable and factor were calculated.

The process of consultation normally begins with the explanation of consultation goals and the determination of controversial issues. At this stage, the most important aspects are: to know whether a consultant is capable of listening to the client and whether the client hears what the consultant is saying. These three variables form the ability to identify the problem (the factor). However, the assessment of this issue slightly differs from the consultant and client point of view, for the key element to clients is the ability to listen (M=4.98), whereas to consultants this element is less important (M=4.18).

The opinion of both the consultants and the clients was mostly different when assessing the factor of consulting methodology. It consists of three variables such as: the application of methods used for providing

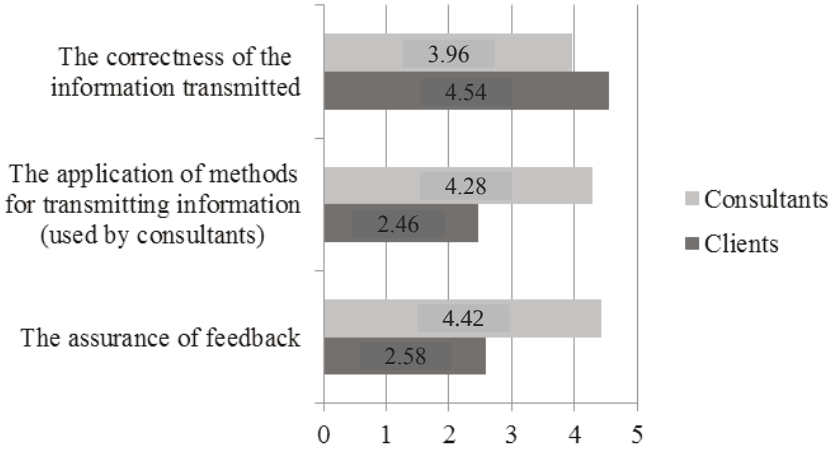

Figure 1. The importance of consulting methods (factors) in numbers.

information, the correctness of the information transmitted and assurance of feedback. If consultants consider the feedback and the application of consulting methods to be the most important variables, then clients pay most attention to the correctness of the information transmitted (see Figure 1).

The analysis of consultants and clients of different consultation companies showed that the consulting methods applied by the consultants of *UAB Kauno teisinių paslaugų centras* and *VšĮ Teisinių paslaugų, audito ir ekspertizės centras* were easily understood by clients, whereas the assessment of methods used by the consultants of *UAB Verslo teisės centras* were not as good as the above-mentioned ones'. All the consultants of the companies aim at ensuring the feedback from clients. For this particular reason, various methods are applied, such as asking to fill in the evaluation form (*UAB Verslo teisės centras*); to express opinions and to put it into "the opinion box" (*UAB Kauno teisinių paslaugų centras and PI Teisinių paslaugų, audito ir ekspertizės centras*).

Referring to the results of the research, the retention of focus, the application of innovations and methods for making influence to human behaviour is much more important to consultants than to clients. The difference of the evaluation of the above-mentioned factors is slight (3.22 and 4.1). There is no doubt that all consultants try to keep the attention of clients; nonetheless, the number of successions is not total, especially when collective methods for consulting and training are applied. In order to maintain the focus of client(s), it is sometimes necessary to use the method of his/their knowledge manipulation, not to reject the client if his knowledge in a particular field is insufficient. The consultants of *UAB Kauno teisinių paslaugų centras* and *PI Teisinių paslaugų, audito ir ekspertizės centras* usually work with clients individually.

In order to determine the influence of factors to business and interpersonal relationship between consultants and clients, respondents (consultants and their clients) were asked to evaluate the importance of factor in the scale from one to five. Thereafter, the averages of these estimates were calculated. The aggregated evaluations of business factors are provided in Figure 2.

The results of the research suggest that the influence of business factors to both the consultants and clients is extremely relevant. Clients particularly appreciate the competence of a consultant, his ability to identify the problem (M=4.88) and to transfer information (M=4.44). Nearly 87 per cent of all respondents (clients) of the survey would like to see a consultant who is capable of identifying the problem quickly and correctly, who would understand what advice to give and provide a complete and competent answer to questions. Namely, these factors were ranked as important and very important. Clients listed the capability of keeping the focus, applying innovations when consulting (M=3.22) and the factors of invoking various consulting methods (M=3.22) as less relevant. The influence of these factors was considered to be more important for consultants, since the importance of these factors was evaluated by more than 4 points in the scale. Such distribution of opinions was mostly determined by different experience of consultants and their clients. Consultants that have greater experience in consulting are familiar with the appropriate selection of consulting method for it leads to the succession of the work, which is, as a rule, not appreciated by clients.

The analysis of factors that have influence on interpersonal relationship reflects its almost equal importance to both the consultants and clients. The ethics of conduct is significantly important for both the consultants and the clients (M=4.65 and M=4.86

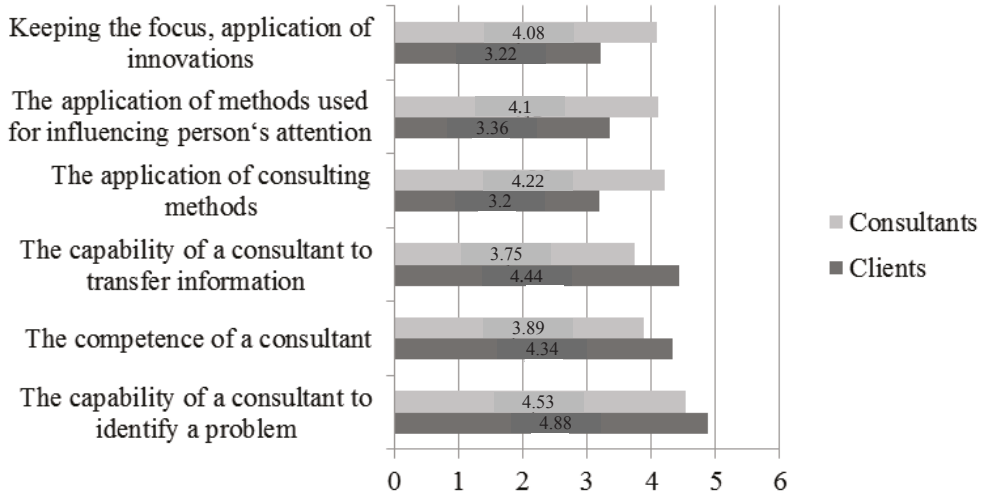

Figure 2. The influence of business factors on the relationship between consultants and clients.

respectively). The clients wish the customers to act confidentially and the relationship to be based on universally acceptable principles and values. The consultants understand that the assurance of confidentiality can help to guarantee a long-lasting communication and to achieve other goals of operational cooperation.

Both groups of respondents rated the capability of overcoming and solving complex situations as well as the ability to behave calmly and kindly to be of the same importance.

The biggest difference of client's and consultant's opinions in the group of interpersonal factors appeared to be the evaluation of communication skills. This factor is extremely important for clients (M=4.64), whereas consultants consider it to be of less importance (M=3.63). Approximately 70 per cent of clients think that consultants should try to look from the client's perspective, sensitively react to their feelings and emotions. However, consultants do not pay much attention to this factor and are tending to provide full information regarding the issue in question and avoid close connection. Both groups of respondents positively rate the respect that consultants show to clients.

In addition to the factors determining the relationship between consultants and clients, much influence has the experience of a consultant, his/her knowledge and skills.

The data received in all three consultation companies were quite similar, for both the clients and the consultants treated the process of consultation favourably. The analysis of the data showed that the assessment of clients in the consulting company *UAB Kauno teisinių paslaugų centras* was more positive than in *PI Teisinių paslaugų, audito ir ekspertizės centras*. Moreover, the consultants of the latter company were less self-confident as well as less eager to evaluate their relationship with clients.

The consultants of *UAB Verslo teisės centras* indicated that they place dependence on their knowledge and information as well as the opportunity for clients to express their opinion. Despite the fact that consultants are quite flexible, they lack feedback. What is more, it was also noted that there are clients whose behaviour is improper. According to the consultants of *UAB Kauno teisinių paslaugų centras* and *PI Teisinių paslaugų, audio ir ekspertizės centras*, not all of them rely on their knowledge and information; not always do clients get an opportunity to express their opinion; sometimes there is a lack of flexibility; much effort is put to ensuring the feedback; consultants behave appropriately and confidentially.

After the assessment of factors determining the efficiency of relationship between consultants and clients, the following suggestions for the improvement of such relationship can be provided:

1. In the level of operational relationship:

A. The consultant's competence to identify the problem has to be developed by improving and training their skills and abilities, attending trainings, courses for the improvement of qualification, seminars, as well as long-term and short-term internships, permanent interest in changes and innovations in a particular professional field. The research showed that clients and consultants consider the consultant's ability to sort out the problem in the level of operational relationship as the main factor determining the communication between these two actors. As a matter of fact, it is significantly important for a consultant to identify and to define the problem, to overview the facts of the

situation as well as to characterize and analyse the roots of the problem.

B. The competence of consultants has to be cultivated; they have to be encouraged to improve their professional skills. When training a consultant to become an expert in his field, the system for the development of competence and refreshment of knowledge should be created. Not only should it provide a consultant with the state-of-the-art information, but also motivate him to seek for perfection. Motivated employees are more responsible, seek for recognition at work, professional improvement, their work is more efficient and the quality of work better. Moreover, there is a greater possibility that the ideas will be realized and the responsibilities taken. For those who lack motivation, work is only a source of income.

C. Consultant's ability to transmit information should be facilitated. Consultants should be encouraged to be more tolerant and develop their communication skills. During consultations clients should have all the possibilities that are necessary for expressing their opinion and concerns. A consultant should allow a client to speak. The chain of communication has to be as short as possible, for it would help to ensure the transparency of disseminated information. The high-quality internal communication is expressed orally and therefore creates a good climate for discussions and questions. It is important for the feedback to take place at the same time.

D. The application of consulting methods is important. Methods of consulting should be based on information and applied in a more precise and understandable manner. Consultants should apply more various methods in their work and explain clients what method is used in order to identify the necessary information. In addition, they should also explain why a particular method is chosen. The feedback of the relationship between consultants and clients is extremely relevant, since it is the stylistic feature of the democratic leadership. Consultants should foster the emergence of feedback as well as listen carefully and react honourably to the suggestions and thoughts of a client.

E. The application of methods used for making influence to human behaviour mostly refers to the development of persuasion skills and efforts to convince a client. When a consultant applies the method of manipulating on clients knowledge, he could use the provocation of protective reactions, confusion and disorientation. Consultants should also try to make an impression that the client is willing to cooperate, to play with his impatience and greed, to use the option of heavy discounts and the sense of hopelessness.

F. Keeping focus, applying innovations are to be considered. The aim of this aspect is to encourage consultants to improve their skills and competences by attending training, qualification courses or seminars.

It is easiest to accept innovations, which are relatively advantageous for the client, meet the values, experience and needs of a client, are simple and can be tested on a small scale. Therefore, namely these criteria are to be taken into consideration when applying innovations in the process of consulting.

2. In the level of interpersonal relationship:

G. The ethics of a consultant should be followed. It is important for the consultant to take into consideration the fact that he is not the only participant in the society and in the field of market. As a matter of fact, he should comply with the norms of ethics and etiquette, as well as to seek for polite communication. Normally, it finally leads to a useful partnership. The personal ethics of a consultant should be based on the highest standards of honour, virtue, justice, honesty, integrity, politeness and impartiality. He should try to avoid injustice in his work as well as to understand the attitude of another person, ethically cooperate in assessing situations and trying to resolve moral dilemma.

H. Conflict management ability is of vital importance. Effectively managed conflicts can become useful. They can help to resolve disagreements, difference of opinions, as well as to change beliefs and the relationship between clients and consultants. However, violent conflicts can lead to severe destructive consequences and, therefore, should be avoided. A good consultant should show respect to others, try to understand the attitude of another person, avoid assertion and highly confident tone.

I. Communication skills of a consultant play an important role. Communication barriers make negative influence on the efficient flow of information, cooperation of a consultant and a client, their relationship and the productivity of work. The communication of clients and consultants should be based on honesty and professionalism which would help to maintain

an appropriate inner climate. If relationship is appropriate, then the communication is more sincere.

Clients and consultants should discuss and argue when trying to defend their opinion, as well as to develop tolerance to the weaknesses of others.

Conclusions

1. Empirical survey of the importance and influence that professional factors have on the client-consultant relationship showed that clients consider the factors which, in their opinion, directly determine the efficiency of consulting to be more important (for example, consultant's ability to identify the problem, to transmit information as well as his competence).
2. Consultants, similarly to clients claim that the factors of various capacities and competence are also relevant. However, factors related to the methodology of consulting are considered to be of the same importance.
3. When assessing the influence of interpersonal factors to client and consultant relationship, both the consultants and clients indicated the importance and ability to manage conflicts as one of the important aspects of ethical conduct during the consultation. However, clients considered the factor of communication skills to be of a higher importance. They wished the consultant had tried to look from their angle and even eager for an emotional contact.
4. Consultant's ability to identify a problem has to be prompted by improving and developing their skills and competences in trainings, training courses leading to qualifications, seminars, long-term and short-term internships and permanent interest in the changes and innovations of this particular professional field. Consultants should also be encouraged to create consultant's memo.
5. When training a consultant to become an expert of his field, the system for competence development and refreshment of knowledge should be created. Not only would it provide a consultant with the latest information, but also motivate him to improve.
6. Consultants should encourage the feedback; listen to the suggestions and opinions of a client carefully and respectfully.
7. A consultant should try to understand the attitude of other person, cooperate in assessing situations and solving moral dilemmas in an ethical manner, as well as avoid injustice in his work. For this particular reason, consultants should follow the code of conduct and/or rules of behaviour with clients. If such rules do not exist, their establishment should be initiated.
8. The research showed that clients and consultants consider the consultant's ability to sort out the problem in the level of operational relationship as the main factor determining the communication between these two actors. As a matter of fact, it is significantly important for a consultant to identify and to define the problem, to overview the facts of the situation as well as to characterize and analyse the roots of the problem.

References

1. Adamonienė R., Šilingienė V. (2006) Consulting outsourcing in agriculture. *Management Theory and Studies for Rural Business and Infrastructure Development: transactions of the international scientific conference*, 5-7 October. Kaunas - Kaliningrad / Estonian University of Life Sciences, pp. 42 – 48.
2. Baršauskienė V. (2003) *Dalykinė komunikacija: mokomoji knyga (Business communication: a practical guidebook)*. Kauno Technologijos Universitetas. Kaunas: Technologija, 376. p. (in Lithuanian).
3. Baršauskienė V., Janulev B. (1999) *Žmogiškieji santykiai: vadovėlis (Human relations: a textbook)*. Kaunas, Technologija, 154. p. (in Lithuanian).
4. Barvydienė V., Kasiulis J. (2003) *Vadovavimo Psichologija: Vadovėlis (Managerial Psychology: Handbook)*. Kauno TechnologijosUniversitetas, Kaunas, Technologija, 327. p. (in Lithuanian).
5. Block P. (2000) *Flawless Consulting: a Guide Getting Your Expertise Used*, Wiley, John & Sons, Incorporated, 480 p.
6. Bowman J.P., Branchaw B.P. (1987*) Business Communication*, CBS College publishing, 111 p.
7. Chreptavičienė V. (2005) *Dalykinio Bendravimo Ugdymo Aktualijos ir Problemos (Business Communication Education Research and Problem)*. Edukologija, 65. p. (in Lithuanian).
8. Fiske J. (1998) *Įvadas į komunikacijos studijas (Introduction to communication studies)*. Vilnius, 200. p. (in Lithuanian).
9. Gayeski D.M. (2000) *Managing the Communication Function*, Capturing, 283 p.
10. Kočiūnas R. (1997) *Psichologinis Konsultavimas (Psychological Counseling)*. Vilnius, Margi raštai, 84. p. (in Lithuanian).
11. Kavalov A.G. (1970) *Psychology of Person,* Moscow, Education, 130 p.

12. Melnikas B., Strazdas R. (1998) *Šiuolaikinė Verslo Konsultavimo Samprata. Socialiniai Mokslai. Vadyba (Modern Business Consulting Approach. Social Sciences. Management).* Kaunas: Technologija, Nr. 3, pp. 60 – 67. (in Lithuanian).
13. Savanevičienė A., Šilingienė V. (2005) *Darbas Grupėse: Vadovėlis (Group Work: a Textbook)*. Kauno Technologijos Universitetas, Kaunas, Technologija, 327. p. (in Lithuanian).
14. Steele F. (1999) *Consulting for Organization Change,*Massachusetts, 249 p.
15. Strazdas R. (1995) *Matomos ir Nematomos Konsultacinės Veiklos Pusės. // Tarptautinės konferencijos „Verslas ir vadyba 95“ pranešimų medžiaga (Visible and Invisible Consultancy Business Side. // International Conference on Business and Management).* Vilnius: Technika, pp. 189 – 193. (in Lithuanian).
16. Van Den Banas A.W., Hawkinsas H.S. (1999) *Žemės Ūkio Konsultavimas [Agricultural Consulting],* Akademija, LŽŪKT, 77 p.
17. Želvys R. (1995) *Bendravimo Psichologija (Communication Psychology).* Vilnius, Valstybinis leidybos centras, 45. p. (in Lithuanian).

THE ROLE OF AGRICULTURE IN ENSURING THE ENERGY SECURITY IN POLAND

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Abstract
The purpose of this article has been to present a range of products which can be obtained from agricultural production and used for energy purposes. The domestic demand for plant material to be converted to biocomponents was assessed, including the demand for oilseed rape seeds and other grain used to make bioethanol in Poland. One of the ways to limit the adverse effect of fossil fuels on the environment is by using renewable resources. Agriculture is the producer of biomass used to make biocomponents for liquid fuels and raw materials for substitution of solid fuels. The EU, wishing to stimulate production of biomass for energy purposes, has brought to life several legal acts which force the use of biofuels in the European Community. Farmers who produce substrate for bio-fuel production were offered subsidies to energy crop plantations, at first paid from the state budget, and in 2007 – 2009 provided under the Common Agricultural Policy (CAP), which increased the farmers' revenues from farming. The decisions approved of while reviewing the CAP are to improve – via the market mechanism – the production and export potential of the whole EU. This is to be achieved, for example, by abolishing the subsidies to energy crops, which ceased to be paid in 2010. Such subsidies improved (artificially) the profitability of energy crop plantations, while causing a relative decrease in food production in Europe. By participating in the CAP, Poland is obliged to undertake certain measures in the domestic policy that will comply with the decisions made on the EU level.
Key words: energy policy, renewable energy sources, Common Agriculture Policy (CAP).

Introduction

Production of biofuels, which dates back to the 1970s, is most often perceived as a desirable and advantageous development, representing a link in a series of actions pursued with the aim of creating alternative, renewable sources of energy, which are frequently seen as eco-friendly (Spiess, 2013). It is commonly believed that agriculture is one of the biggest pools of RES. The degree to which the potential of agriculture for RES generation is actually utilized depends on a number of factors, e.g. market situation, economic support, costs of production of renewable and conventional energy or the technological progress. However, it seems that a special role should be played by the state's active policy, without which the growth of biofuel production could never be so dynamic. Among the most crucial arguments in favour of developing such a policy are: an increasing demand for energy due to the social and economic progress; higher energy prices and the consequent pressure to limit the export of crude oil; diversification of energy sources and achievement of energy self-reliance (energy security); environmental considerations and the pressure on using renewable energy resources; low prices of agricultural produce and surplus agricultural production in most developed countries, which in the early stage make the above policy more readily acceptable; finally, production of RES enables farmers to raise their income (Figiel and Hamulczuk, 2013).

Predictably, the above vision of agriculture will strongly affect global policies and economies in the long term. In an effort to define contemporary challenges, the European Commission put forth the strategy called Europa 2020 (2010), which is to guarantee an intelligent, sustainable and socially inclusive economic development. This document states that sustainable policy measures in the energy sector will be reaching a 20% decrease in greenhouse gas emission until 1990 (with a possible 30% reduction if relevant international agreements are concluded), a 20% decrease in energy consumption relative to the EU programmes for the year 2020, an increase of the share of RES up to 20% of the total energy consumption in the EU, with an exact percentage adjusted to individual countries relative to their fuel budgets and potential development of renewable energy production. Poland has been obliged to achieve a 15% share of RES in the total energy consumption and a 10% increase in the contribution of biofuels to the total consumption of transport fuels (Pająk and Mazurkiewicz, 2014).

One of the major aims of the Common Agricultural Policy (CAP) is an improved efficiency of farming achieved with no detriment to the natural environment (The National Centre …, 2010). Growing problems of climate change, bioenergy and water resources management will have a considerable influence on of the CAP (Preparing for the "Health Check" of the CAP reform, 2007), leading to the transformation of the overriding aim of agricultural production, such as food making. The CAP's second pillar includes multi-year funds dedicated to the development of rural areas in order to enhance their competitiveness, to manage natural resources in a sustainable way and to support the development of farms.

The EU countries are observed to be experiencing a change among consumers and residents regarding their expectations towards agriculture. Having a broader knowledge on multi-faceted agriculture, including production of feedstock for energy

generation, the society more readily supports farming as the type of economic activity which supplies not only basic marketable products but also other types of goods, including public ones. It can be expected that the paradigm of multi-functional agriculture will be fundamental to the CAP as well as to the practical solutions it will propose.

Agriculture has an important role to perform in economy, society and environment. It will be impossible to engage agriculture in the system of sustainable development of rural areas unless its multi-functional character is taken into consideration. Thus, the policy of rural development is based on two concepts: multi-functionality and sustainable development.

The European Union is a leader in the promotion and implementation of renewable energy sources. In quantities, the dominant renewable energy carrier is and will continue to be biomass. The most important sources of biomass include timber from forests and orchards, short rotation plantations of woody plants (e.g. willow-*Salix*) and wood processing byproducts; energy crops, for example seeds from oil plants processed into esterified oils, which are then used as fuel, potato tubers – *Solanum tuberosum*, beetroots - *Beta vulgaris*, cereal grains processed into ethyl alcohol added to petrol, organic residue and waste – straw and other plant remains generated during agricultural production as waste, waste generated by the food processing industry, organic municipal waste, organic industrial waste (from paper and cellulose manufacturing) (Janowicz, 2006). Biomass can be used for energy purposes, for example by combustion of solid bio-fuels or co-combustion with coal in furnaces (esters of oilseed rape oil, ethanol, methanol) or gases (agricultural biogas, biogas from wastewater treatment plants, biogas from landfills). The actual way in which biomass is converted into energy carriers depends on its chemical composition. Biomass conversion to energy carriers can be achieved by physical, chemical and biochemical methods (Bielski, 2012).

Climate change as a challenge has found its reflection in the CAP, and the evolution of agriculture towards the non-food use of agricultural products has become an important element of many research projects in Poland and in the whole EU. Production of biofuels will have a considerable impact on agriculture. However, a conflict arises between the food production security and undesirable climate changes, with the latter possibly limited by the replacement of fossil fuels with biofuels.

Materials and Methods

The purpose of this article is to discuss agricultural products which could be used for generation of energy. Another objective has been to show the increasingly important role of renewable energy sources (RES) originating from agriculture in the Polish energy balance. The discussion is set in the context of financial subsidies available under the Common Agricultural Policy (CAP) and dedicated to production of energy feedstock in agriculture. The analysis has relied on some relevant references, legal regulations, statistical data and our own calculations. The data supplied by the main Statistical Office (GUS) and the National Index Target set for the years 2014-2020 enabled the authors to assess the demand for biocomponents, the raw material need to produce them and the land area needed for growing the required amounts of biomass. The data are presented in tables and descriptions.

Results and Discussion

According to the Polish law, and more specifically Article 1 (2) of the Energy Law (1997), the principal aims of the Polish energy policy are as follows: to create conditions for the country's sustainable development, ensure the energy security of Poland, promote economical and rational use of fuels and energy, stimulate competition, counteract negative consequences of monopolies, respond to the requirements imposed by the natural environment conservation and protection, and finally to protect interests of energy consumers and minimize costs. One of the main priorities defined in the document titled "The Polish Energy Policy until 2030" is to promote renewable energy sources and to increase their consumption.

Maintaining energy balance in a country involves the sustainable adjustment, both current and long-term, of the supply of energy and fuels. Economic and ecological aspects should be considered as well as the potential management of energy demand, without restricting the needs of consumers to be provided with usable energy. Definitions of energy security emphasize the aspect of environmental protection. This is one of the reasons why the role of RES is taken into account when ensuring the state's energy security. In the near future, development of renewable energy sources will be one of the priorities (Borgosz-Koczwara and Herlender, 2008). This is also an important problem for other countries, regions, Europe and the world. Forecasts suggest that energy consumption will increase by 60% until 2020. The increased global demand for energy (especially in China, India or Brazil) should be satisfied not just by supplying more coal, oil or natural gas, but also by developing RES (solar, wind power, or tidal power, as well as geothermal power and energy accumulated in biomass) (Bielski, 2011a).

The dynamic increase in biofuel production stimulated by the policy supporting the development

of this branch of energy generation has contributed to some increase in the prices of agricultural products and foods; it has also added to higher fluctuations in these prices. Farmers whose revenues have increased are beneficiaries of the discussed policy. The positive effect of such a policy is notable mainly in developed countries. In less developed ones, however, some negative results can be seen, e.g. a threat to the food security. The gain and loss balance is therefore less than obvious. The uncertainty and price risk have risen and food consumers everywhere, also in more affluent countries, can feel the negative consequences of higher and more volatile prices of agricultural products. For that reason, relaxation of the strict EU policy with respect to the minimum share of biocomponents in fuels is worth considering. Another noteworthy aspect is that the energy potential of biomass is rather limited. Some analyses seem to indicate that if the whole biomass produced by agriculture worldwide was used for energy generation, it would satisfy 10% of the global energy demand (Figiel and Hamulczuk, 2013).

The regulation of the European Commission Council of 2003 laid the legal foundation for special subsidies given to agricultural producers who grow energy crops. The rate of payments was 45 EUR·ha^{-1}, but there was the budget threshold consisting of the maximum guaranteed acreage of 1.5 million ha. Any excess of this limit was to cause a proportional decrease in subsidies. In late September 2006, the European Commission proposed to cover the new member states, who had not profited from such subsidies, with the same support scheme for growing energy crops. The aim was to raise their interest in energy crops and to include permanent plantations into the system of direct payments. Farmers were eligible to receive payments for crops grown for energy purposes, according to Art. 2 Item 1 of the European Commission (2004) if the declared acreage was at least 0.3 ha. Yields representative for particular energy crops were announced annually in a regulation issued by the Ministry for Agriculture and Rural Development, having considered average yields of individual energy plant species per hectare. Plants whose cultivation entitles the farmer to apply for energy crop payments were specified. Payments to the area of farmland under energy crops were granted on condition that the yields had been contracted and plants had been processed into energy products (European Parliament, Council of the European Union, 2009).

The Rural Areas and Agriculture Development Strategy 2007 – 2013 (2005), where within the frameworks of the "Support to sustainable development of rural areas" the plants that can be cultivated for energy generation purposes is also important for development of energetic plants production development (Bielski, 2011b).

In 2007, there was so much interest in growing energy crops among farmers that the maximum limit of farmland under energy crop plantations was exceeded and it was necessary to reduce the acreage which entitled plantation owners to payments. The reduction rate was 0.70337. In the European Union, the implementation of the payment scheme began in 2004, when the total acreage of energy crop plantations was 0.31 million ha. Afterwards, it grew to 0.57 million ha in 2005 and 1.23 million ha in 2006, reaching 2.84 million ha in 2007. In Poland, energy crop plantations covered 3507 ha in 2005 and 6113 ha in 2006, growing to 175381 ha, including 6816 ha of permanent plantations, in 2007, 62904 ha in 2008 and 10198 ha in 2009. In 2010, subsidies to energy crop plantations were stopped, having reached the aim, such as the total acreage of 2 m ha. However, energy crop producers could take advantage of direct payments, which they are entitled to also when growing non-food plants. Despite being lower than in other EU countries, direct payments in Poland are the most significant contributor to Polish farmers' revenues. The Common Agricultural Policy claims that one of the purposes of direct payments is to raise farmers' income above what they would be able to earn from selling their own non-food products (Marks-Bielska, 2010). The highest sums resulting from complimentary national area payments were cashed in Poland in 2007 – 12.4 million PLN, in 2008 – 6.8; in 2009 – 8.4 million PLN. In 2005 (0.8) and in 2006 (1.7 million PLN) payments to plantations of willow or thorn-free rose grown for energy use were funded from the state budget.

Under the CAP, the generation of renewable energy derived from agriculture was supported by direct payments in the first pillar; moreover, it is possible to take advantage of the five measures in the Rural Development Programme (the RDP) for 2007-2013 (the CAP's second pillar, i.e. measures for the sake of development of rural areas). In order to stimulate the production of feedstock for renewable energy generation, the European Commission suggested that the member states be allowed to offer national support, up to 50% of starting a permanent plantation of energy plants, available on these parcels of farmland for which farmers submitted applications for support eligible to energy crop plantations (Bielski, 2012).

In November 2009, the decisions finalizing a review of the Common Agricultural Policy (so-called Health Check) were approved. The review was a continuation of the CAP reform, initiated in Luxembourg in 2003. It led to the publication of the European Council (EC) Regulation 72/2009, of 19 January 2009, which replaced Regulation 1782/2003,

Table 1

Forecast demand for primary and renewable energy in Poland

Specification	Units	Years			
		2015	2020	2025	2030
Primary energy	Mtoe	95.8	101.7	111	118.5
Renewable energy	Mtoe	8.4	12.2	13.8	14.7
The share of renewable energy in total primary energy consumption	%	8.8	12.0	12.4	12.4

Source: Marks-Bielska and Bielski, 2013.

previously regulating questions of awarding direct payments. The solutions which then entered into force contain several modifications which will necessitate changes in the regulations governing the scheme of direct payments in Poland (European Union, 2009). The decisions sanctioned as a result of the CAP review were intended to raise, via the market mechanism, the production and export potential of the whole EU. This in particular was to be achieved by abolishing subsidies to energy crops starting from 2010. These subsidies improved (artificially) the profitability of energy crop plantations, causing a relative reduction of food production in the EU.

An increase in the share of RES in the fuel and energy balance contributes to the improved efficiency at which fossil fuels are used and saved. It also adds to a better quality of the natural environment owing to a lower emission of pollutants and less waste (Goldemberg, 2007; Borgosz-Koczwara and Herlender, 2008).

The predicted increase in the demand for primary energy until 2030 in Poland equals about 27% versus the year 2010. The share of renewable energy in the total primary energy consumption will rise from about 8.8% in 2015 to 12% in 2020 and 12.4% in 2030 (tab. 1).

Agricultural biomass (one of the major renewable energy sources) is considered to be the source of the highest energy potential. With respect to the degree of its processing, biomass can be divided into primary (annual and perennial energy crops, surplus biomass from permanent pastures unused by animal production) and secondary (waste and byproducts from agricultural production and food processing: liquid and solid animal waste, organic residue from the food production industry, e.g. glycerin, distillers grain, slaughter offal, dairy wastewater, etc.). The importance of the agricultural biomass energy potential is unquestionable, but there are rather big differences between its estimates (Gajewski, 2011).

Biomass is a typical local fuel and should be used locally by individual consumers, as the main fuel in distributed energy and heat co-generation plants. Using biomass resources for energy purposes depends on a number of factors, including economic incentives (Bielski, 2012), or technological progress. Until recently, Poland has lacked mechanisms connecting the agricultural biomass demand with the possible productive output of agriculture. At present, the question of agricultural biomass is included in the document titled Strategy for sustainable development of the countryside, agriculture and fisheries for 2012-2020. An exhaustive description of this issue can be found in the Specific Measure 5. protection of the environment and adaptation to climate change in rural areas, in priority 5.3. Adaptation of agriculture and fisheries to climate change and their contribution to counteracting such change (mitigation), and in Priority 5.5. Increasing the use of renewable energy sources in rural areas.

The acreage covered by plants suitable for production of bioethanol (starch and sugar feedstocks: cereal grain, potato-*Solanum tuberosum*, maize-*Zea mays*, sugar beet-*Beta vulgaris*) depends on factors related to the natural conditions and the organization of production because the cultivation of such plants must comply with the criteria of sustainable development (The European Parliament Directive 2009). However, the main limiting factors belong to the realm of economics, with energy crops grown mostly on poorer soils, which produce lower yields and consequently the costs of bioethanol production are higher. A major constraint on bioethanol production is the availability of biomass feedstock (Balat, 2011). The situation is very much the same in respect to methyl esters of fatty acids (biodiesel). Data on the forecast growth in the demand for higher fatty acid esters and bioethanol, and consequently the acreage needed to satisfy this future demand, are contained in table 2, indicating that over 1.5 million ha of farmland should be secured in Poland in 2014 for the purpose of ester production.

The assessment of the domestic demand for oilseed rape seeds must include an area needed to satisfy the demand of the food industry (about 450 thousand ha). Our analysis of the data suggest that in 2014 almost 2.0 million tons of grain should be processed to bioethanol in Poland. It is difficult to predict precisely how much farmland will be needed to produce such an amount of grain because various species of cereals could be grown and some bioethanol could be imported.

Table 2

Forecast demand for energy oilseed and grain for bioethanol in Poland

Years	Biocomponent demand (ths. m^3)	Feedstock demand (ths. Mg)	Demand for cropped area (ths. ha)
oilseeds			
2014	1 224	3 549	1 470
2020	1 593	4 621	1 913
grains			
2014	589	1 944	486
2020	780	2 574	644

Source: the authors, based on the national Index target for 2014 – 2020, including the diesel consumption on the level of 15 018 thousand m^3 and petrol of 5 166 thousand m^3 (the average consumption of fuels in 2011 – 2012), providing that the energy consumption in the consecutive years would remain at the unchanged level.

The European Union takes a stand on the reduction of CO_2 emission, claiming that it can be achieved by developing second generation biofuels (obtained by processing lignin cellulose raw products). The essence of second generation biofuels is the use of waste products, useless in food production. Straw is an example of agricultural produce which may be used for energy generation. Kuś and Faber (2009) calculated that the surplus of straw produced by the Polish agriculture is about 9 million tons, of which at least 30 – 40% can be used for alternative purposes, including energy generation. Realistically speaking, about 3 to 4 million tons of straw can be used to produce energy.

However, in order to meet the increasing demand for biomass, it will be necessary to harvest it from dedicated plantations of perennial plant species. Biomass for energy purposes can be obtained from several plant species, but in practice their choice will depend on habitat conditions, costs of purchasing seedlings or plantings, the equipment available on a given farm, and the way in which biomass is to be utilized. The most important species are: miscanthus-*Miscanthus*, short rotation willow-*Salix*, Pennsylvania fanpetals-*Sida hermaphrodit*, reed canarygrass-*Phalaris arundinacea*, giant knotweed-*Reynoutria sachalinensis* and Jerusalem artichoke-*Helianthus tuberosus*. Due to the shortage of biomass from dedicated energy crop plantations on the market, a further increase in the energy use of straw is expected. In the short term, the development of agriculture dedicated to production of energy crops will force to cover from 1.5 to 2 million ha of farmland for production of energy biomass (Kuś and Faber, 2009).

Another aspect of ensuring the country's energy security is the promotion of distributed, low-power energy sources, generating energy locally and supplying it directly to farmsteads and households. These criteria are best met by renewable energy installations: biomass furnaces, micro-biogas plants, small water turbines and solar batteries. Installing such technologies in agriculture, that is generation of energy by a farmer for their own use, enables lowering the amount and cost of energy bought from external sources, which translates into measurable financial gains. It can also help to control the noxious aspects of agricultural production, for example when plant or animal production waste, such as liquid manure, is converted to energy. The rational employment of such local energy sources creates benefits for a single farm as well as for whole agriculture. When a farm uses energy from renewable resources, it can replace with it increasingly less available to farmers and more expensive non-renewable fuels, such as coal or oil coke for generating electric energy or heating buildings and water, as well as liquid fuels (natural gas, liquid gas, diesel oil, heating oil) used to power engines or for heating buildings. Price relations between the above conventional energy carriers to RES, compounded by problems in ensuring the energy security of all individual energy consumers by conventional, large-scale energy companies, create opportunities for the development of numerous renewable energy installations, which are currently more profitable (Oniszczak-Popławska et al., 2011).

One of the most prospective directions in the energy use of biomass resources is thought to be agricultural biogas production. A biogas plant is an installation designed specifically to produce biogas from plant biomass, animal waste or organic waste (e.g. from the food industry). Unfortunately, this direction in the energy conversion of biomass has not developed to a satisfactory degree. The low share of agricultural biogas in the total energy production is due to a small number of working agricultural biogas plants (according to the Register of energy enterprises producing agricultural biogas of 17 March 2014, there were 39 such installations). The reasons could be certain formal barriers to building biogas plants (including the economic, legal and technological obstacles) as well as the low availability of feedstock (Fugol and Szlachta, 2010).

Biogas plants could supplement the national energy production capacity, especially when the theoretical potential has been estimated at the level of 5 billion m^3 of biogas annually, while the actual potential, based on waste products generated by agriculture and the food industry is assessed at 1.7 billion m^3 of biogas annually. Such quantities of biogas could cover about 10% of the domestic demand for gas or, in other words, could completely satisfy the energy needs of the rural population in Poland (Ministry of Economy, 2010).

It is possible to install thousands of small wind power generators directly on farms in the rural areas in Poland. This would translate into a significant support to the national plans to fulfill Poland's international obligations in terms of reduced CO_2 emission and decreased combustion of fossil fuels for commercial energy generation. The solution might also bring about several social benefits, for example, by creating conditions for industrial production of construction components necessary to build small wind power plants, stimulating the general interest in renewable energy sources in the countryside, encouraging the research and development in the scope of building small wind power plants, etc. Turowski and Nowowiejski (2010) claim that it would be feasible to achieve a 50% decrease in electric energy purchase by a farm equipped with its own energy source. In addition, the farmer could earn an additional income by selling surplus energy to an energy distributor.

By participating in the Common Agricultural Policy, Poland is obliged to undertake certain measures which comply with the decisions taken on the level of the European Union. The main goal of the development of RES in Poland is to fulfill, by the year 2020, the criterion regarding the share of RES in the final energy consumption, and to further improve its contribution in the following years. In 2006 – 2012, the use of RES in Poland kept increasing by an average 7.8% annually. At the end of that time period, nearly three-fold more energy was generated from renewable resources than in 2005, and the amount of RES produced in 2008 – 2009 was 10% higher than predicted. The dynamic growth was attainable mainly owing to the mechanism of green certificates. On the other hand, since 2005 consumption of electricity has been growing faster than predicted, which makes it more difficult to achieve the assumed growth rate parameters for RES. This tendency can continue until 2020, when the share of RES in the electric energy production could be 1.25% higher than expected. In the above circumstances, it will not be possible to attain the aims of the national energy policy unless available renewable energy sources are developed more dynamically. In Poland, the highest potential among RES can be attributed to biomass resources and wind power, but other sources such as photovoltaic energy or energy generated from municipal waste should not be overlooked. All these actions in Poland will call for the enlargement of the current system of renewable energy generation support by introduction of the guaranteed prices mechanism. Acceleration of the RES development in Poland will also need mechanisms to encourage private capital and to gain approval of local communities towards renewable energy installations. In the Polish conditions, the best solution might be the introduction of the so-called local property (inclusion of local communities in the financing of investments into RES installations in return for the possibility to buy less expensive energy or to participate in profits) (Pająk and Mazurkiewicz, 2014).

Conclusions

As presumed, the authors have suggested what types of feedstock for energy generation can be obtained from agricultural production. The rapidly increasing role and importance of renewable energy sources (RES) from farming in Poland's energy balance have been discussed. The arguments were set in the context of the financial support available under the Common Agricultural Policy (the CAP) and dedicated to energy crops. The analysis of statistical data and legal regulations has led to the following conclusions:

1. The most popular energy types of feedstock, which can be produced by the Polish agriculture, are cereal grains, oilseed rape seeds (basic raw products for production of liquid biofuels) and maize silage (production of agricultural biogas).
2. The current tendencies show that the most dynamically developing branch on rural areas will be the renewable energy generation. Agriculture will play a new role in the future. As well as producing food, it will supply biomass used for energy generation.
3. In agreement with the global tendencies, agriculture in Poland will perform a significant function in attaining goals connected to renewable energy sources. Apart from supplying feedstock, rural areas will develop their own installations for converting it into energy, so that biomass will be used locally, where it is produced.
4. Because of their distributed character and use of local resources, renewable energy sources can become an element which to some extent will contribute to ensuring energy security; they will also help to lower energy costs.
5. The growing acreage cropped with energy plants in Poland so far has been stimulated by economic decisions, e.g. an effort to raise income by gaining support to energy crop plantations in the first

years after Poland's access to the EU, when Polish farmers became eligible to apply for the CAP instruments, first provided by the state budget and then from the EU funds (especially after 2007, when the list of eligible farmers was extended by adding subsidies to annual plantations, including cereals and oilseed rape).

6. As well as incentive such as subsidies and payments for producers of energy crops, the EU has also created many obligatory legal regulations, which force the member states to implement the Community's decisions.

References

1. Balat M. (2011) Production of bioethanol from lignocellulosic materials via the biochemical pathway: A review. *Energ Convers Manage*, (52), 2, pp. 858 – 875.
2. Bielski S. (2011a) Policy concerning biocomponents of liquid fuels in Poland in the context of legal conditions. *Polityka ekonomiczna*, Zesz. Nauk. AE Wrocław, no 166, pp. 48 – 58.
3. Bielski S. (2011b) Conditions of biomass production for energy generation purposes in Poland. Folia Oeconomica Stetinensia, 1(10), pp. 238 – 249.
4. Bielski S. (2012) Energy feedstock production in Poland in the context of the Common Agricultural Policy. *Finanse i Marketing*, 8(57), pp. 47 – 59.
5. Borgosz-Koczwara M., Herlender K. (2008) Energy security and the development of renewable energy sources. *Energetyka*, 3, pp. 194 – 219.
6. Council of Ministers (2012) The sustainable development of rural areas, agriculture and fisheries for the years 2012 – 2020. Available at: http://www.infor.pl/monitor-polski,rok,2012,nr,163.html, 14 February 2014.
7. Council of the European Union (2009) Council Regulation (EC) No 73/2009 of 19 January 2009 establishing common rules for direct support schemes for farmers under the common agricultural policy and establishing certain support schemes for farmers, amending Regulations (EC) No 1290/2005, (EC) No 247/2006, (EC) No 378/2007 and repealing Regulation (EC) No 1782/2003). Available at: http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.L_.2009.030.01.0016.01.ENG, 14 February 2014.
8. European Commission (2004) Commission Regulation (EC) No 1973/2004 of 29 October 2004 laying down detailed rules for the application of Council Regulation (EC) No 1782/2003 as regards the support schemes provided for in Titles IV and IVa of that Regulation and the use of land set aside for the production of raw materials. Available at: http://eurlex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2004:345:0001:0084:en:PDF, 14 February 2014.
9. European Commission (2010) Europe 2020. A European strategy for smart, sustainable and inclusive growth. Available at: http://eur-lex.europa.eu/legal- content /EN/ TXT/HTML/ ?uri=CELEX:52010DC2020&from=pl, 14 February 2014.
10. European Parliament, Council of the European Union (2003) Directive 2003/30/EC 8 may 2003 r on the promotion of the use of biofuels or other renewable fuels for transport, pp. 1 – 7.
11. European Parliament, Council of the European Union (2009) Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC, pp. 16 – 62.
12. European Union (2003) Council Regulation (EC) No 1782/2003 of 29 September 2003 establishing common rules for direct support schemes under the common agricultural policy and establishing certain support schemes for farmers and amending Regulations (EEC) No. 2019/93, (EC) No. 1452/2001, (EC) No. 1453/2001, (EC) No. 1454/2001, (EC) No. 1868/94, (EC) No. 1251/1999, (EC) No. 1254/1999, (EC) No. 1673/2000, (EEC) No. 2358/71 and (EC) No. 2529/2001. Available at: http://faolex.fao.org/cgi-bin/faolex.exe?rec_id=032213&database=FAOLEX&search_type=link&table=result&lang=eng&format_name=@ERALL, 14 February 2014.
13. European Union (2009) Available at: http://ec.europa.eu/agriculture/healthchec/index_en.htm, 1 February 2014.
14. Figiel Sz., Hamulczuk M. (2013) Development of biofuel production and food security - implications for economic policy. New developments of the CAP 2013+ to face the challenges of agriculture of the Member States of the European Union Competitiveness Polish food economy in the conditions of globalization and European integration. Institute of Agricultural and Food Economics, Warsaw, 91, pp. 147 – 160.
15. Fugol M., Szlachta J. (2010) The reason for using corn and fermented liquid manure ensilage for biogas production. *Inżynieria Rolnicza*, 1(119), pp. 169 – 174.

16. Gajewski R. (2011) The market potential of biomass as a source for energy, *Czysta Energia*, 1, pp. 22 – 24.
17. Goldemberg J. (2007) Ethanol for a sustainable energy future. *Science*, vol. 315, no 5813, pp. 808 – 810.
18. Janowicz L. (2006) Bio-mass in Poland. *Energetyka*, 8, pp. 601 – 604.
19. Kuś J., Faber A. (2009) Crop production for energy and the rational use of Polish agricultural production. The future of the agri-food sector and rural areas. *Przyszłość sektora rolno-spożywczego i obszarów wiejskich*, red. A. Harasim, pp. 63 – 76.
20. Marks-Bielska R. (2010) The market of agricultural land in Poland – conditions and development trends. Olsztyn, Poland, 19 p.
21. Marks-Bielska R., Bielski S. (2013) The increasing role of agriculture to ensure national energy security. Wieś i Rolnictwo, 4(161), pp. 149 – 160.
22. Ministry of Economy (2009) Polish Energy Policy until 2030 r., no 202/10, pp. 1 – 29.
23. Ministry of Economy (2010) The directions of development of agricultural biogas plants in Poland in the years 2010-2020, the program document, pp. 1 – 23.
24. Oniszczak-Popławska A., Curkowski A., Wiśniewski G., Dziamski P. (2011) Renewable sources of energy on the farm. Energy on the farm. Warsaw, Poland, pp. 5 – 17.
25. Pająk K., Mazurkiewicz J. (2014) The support instruments for renewable energy sources development. *Polityka gospodarcza w okresie transformacji i kryzysu*. red. A. Barteczek, A. Rączaszek., 251 p.
26. Polish Parliament (1997) The Energy Act of 10 April 1997 r. Available at: http://isap.sejm.gov.pl/DetailsServlet?id=WDU19970540348, 14 February 2014.
27. Spiess W.E.L. (2013) Does Biofuel Production Threaten Food Security. IU-FoST Food Security. Available at: http://worldfoodscience.com/content/doesbiofuel-production-treaten-food-security, 14 February 2014.
28. The National Centre for Balance Emissions Management (2010) The report of the National Centre for Emissions Management. National balance of SO2, NOx, CO, NMVOC, NH3, particulate matter, heavy metals and POPs 2009-2010 SNAP classification system and NFR. Available at: http://www.kobize.pl/materialy/Inwentaryzacje_krajowe/2012/Raport_LRTAP_2010.pdf, 14 February 2014.
29. Turowski S., Nowowiejski N. (2010) Farmstead wind power plant the source of inexpensive electric energy, *Inżynieria Rolnicza*, 7, pp. 215 – 222.

VALUATION OF AGRICULTURAL EXTERNALITIES: ANALYSIS OF ALTERNATIVE METHODS

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Abstract
The paper focuses on the analysis of agricultural externalities and their valuation methods. Agricultural activity beyond supplying food and fibre, can also be instrumental in forming the landscape, providing natural resources, and preserving biodiversity. Furthermore, agriculture contributes to the achievement of societal goals such as the viability of rural areas and their development, food security, and preservation of cultural heritage. Positive externalities of agriculture assert in the form of public goods, whereas intensive environmentally unbalanced agricultural activity causes damage to the environment. The objectives of this paper are to define agricultural externalities and to analyse methods of their valuation. In order to achieve the research aim, characteristics of agricultural externalities in farming systems have been analysed; evaluation methods of the benefit and cost of externalities in farming systems, revealing their advantages and disadvantages have been examined, and scientific studies on evaluation of externalities have been reviewed. Methods of systemic and logic analysis were applied for analysis of agricultural externalities and their evaluation. The analysis has showed that stated preference methods are commonly used for determination of the positive externalities. The most limited methods are travel cost and hedonic pricing methods, which are suitable only for the evaluation of public goods related to recreation or leisure. For evaluation of negative externalities the external costs of agricultural activity are estimated.
Key words: agriculture, externalities, farming systems, external benefit, external cost.

Introduction

Society has predominantly viewed agriculture only as a food producer, and the science of economics has long concentrated on the issues of intensification of agriculture and promotion of its economic efficiency. However, other aspects, such as food safety and security, preservation of biodiversity, family farms, local culture and rural traditions are gaining greater importance despite the society's view towards agriculture as "the quantity at the lowest prices". The long list of negative externalities also leads scientists and politicians to concentrate not only on the increasing of the efficiency of agriculture, but also on inclusion of the effects of externalities into the total benefit from agriculture. It is obvious that all farms and enterprises seek higher production efficiency. However, creation of marketable goods and services is accompanied by agricultural externalities, which are non-marketable goods and services created by the agricultural activity. They come in the form of uncompensated damage or benefit to the third parties. These values must also be taken into account when evaluating the efficiency of agricultural activity. Moreover, provision of positive and negative externalities from intensive and extensive farming systems is different. Therefore, integration of externalities into the total value of agricultural activity could be useful for politicians who support the multifunctional agriculture and sustaining the effectiveness of the policy. Having determined the benefit and cost of externalities, it is easier to assess the efficiency of farming systems. This is essentially important for farms, the agricultural activity of which has great impact on environment by creation of positive and negative externalities.

Members of the academia are becoming more and more interested in evaluation of agricultural externalities. Research on valuation of agricultural externalities has been done at the national, regional, and farm level. There are studies that focus on estimation of the total external cost (Pretty, 2000; Hartridge and Pearce, 2001; Tegtmeier and Duffy, 2004), while other studies choose a specific group of externalities, for example, soil erosion (Pimentel et al., 1995; Ribaudo et al., 1999), location (Vanslembrouck et al., 2005; Le Goffe, 2000), or agricultural activity (Szabó, 2010). Thereby, scientists often concentrate on the analysis of positive or negative externalities. Although there is a great interest among scientists towards estimation of external cost and benefit and their integration into the assessment of efficiency of farming systems during the last decade, little effort has been made to estimate the cost and benefit of externalities by integration.

The objectives of this paper are to define agricultural externalities and to analyse methods of their valuation. The paper is structured as follows. The first section of the results and discussion analyses the main characteristics of agricultural externalities with a focus on intensive and extensive farming systems. The following section outlines the main valuation methods appropriate for determination of the benefit and cost caused by externalities. Attention is given to the differences between valuation methods and specifics of their application. Findings of recent studies on valuation of agricultural external benefit and cost

are also presented in this section with the discussion on valuation of positive and negative externalities. Conclusions are drawn in the last section of the paper.

Materials and Methods

In order to achieve the research aim, analysis of economic scientific literature was done, characteristics of agricultural externalities in farming systems have been analysed; evaluation methods of the benefit and cost of externalities in farming systems, revealing their advantages and disadvantages have been examined, the necessity of externalities evaluation was substantiated. The main focus was given to the analysis of environmental valuation methods as stated and revealed preference and cost methods.

Methods of systemic and logic analysis were applied for analysis of characteristics of agricultural externalities.

Results and Discussion

1. Characteristics of agricultural externalities in farming systems

According to the agro-technological approach, farming systems are divided into intensive and extensive farming systems. Traditionally they are supposed to be alternative farming or agricultural systems. Intensive farming is also designated as high-input farming system (Poux, 2008; Nemecek et al., 2008) or conventional farming system (Pacini et al., 2003; James et al., 1990) in scientific literature.

However, a lot of changes in the definition of extensive farming systems have occurred during the recent decades. These systems were designated to be low chemical, energy conserving, recourse efficient etc. Scientists have been using definitions of alternative, biological, natural and sustainable agriculture. In the modern scientific studies, extensive farming systems are designated as low-input farming systems (Elbersen and Andersen, 2008; Poux, 2008; Nemecek et al., 2008; Viaux, 2008; Caballero, 2007), extensive farming systems (Vickery et al., 2004; Stott et al., 2005), low intensity farming systems (Beaufoy et al., 1994; Gómez Sal and González García, 2007). Therefore, when analysing scientific literature on farming systems these definitions could be interpreted as synonyms.

The review of scientific studies (Pacini et al., 2003; Nieberg, 2004; Viaux, 2008; Scmid et al., 2008) has shown that low-input farming systems bring great benefits: environmental, social and health, including landscape aesthetic value, recreation, soil formation, flood protection and absorption of gas emissions. These farming systems are hardly dependent on external energy and input, almost do not suffer from soil erosion, preserve biodiversity, create job places for rural inhabitants, and provide high quality food for consumers. Environmental problems such as biodiversity loss caused by intensive use of herbicides and other fertilisers are increasingly emphasized in the academic studies (Reiganold et al., 1990; Poux, 2008; Nemecek et al., 2008). On the one hand, intensification of agricultural activity leads to negative externalities in the form of loss of quality of natural habitats, water, air and soil pollution. On the other hand, it is usually related to economic efficiency of production and creation of marketable goods.

Thereby, agricultural externalities are non-marketable goods and services created by agricultural activity in the form of uncompensated damage or benefit for the third parties. An externality is any action that affects the welfare of an individual or group without direct payment or compensation and may be positive or negative. The types of externalities encountered in the agricultural sector have five features: J. Pretty et al., (2000, p.114) emphasize five features of the types of externalities encountered in the agricultural sector: "their costs are often neglected; they often occur with a time lag; they often damage groups whose interests are not represented; the identity of the producer of the externality is not always known; they result in sub-optimal economic and policy solutions".

The scientific literature analysis (Jianjun et al., 2013; Grammatikopoulou et al., 2012; Vanslembrouck et al., 2005 Kubíčková, 2004; Yrjola and Kola, 2004; Tegtmeier and Duffy, 2004; Le Goffe, 2000; Krumalova, 2002; Pretty et al., 2000) allows distinguishing the most common externalities of farming systems (table 1). They are positive or negative effects created by the agricultural activity in the form of uncompensated damage or benefit for consumers or producers.

All farming systems are multifunctional, which refers to the fact that agricultural production provides not only food and fibre, but also various non-market commodities. A range of studies (Nieberg, 2004; Viaux, 2008; Scmid et al., 2008) have acknowledged that extensive farming systems usually are the creators of the positive externalities (as cultural and traditional heritage; biodiversity is also the habitat for flora and fauna, enhances the aesthetic value of landscapes, provides conditions for recreation, as well as maintains viability of rural areas i.e. increases employment in rural areas, absorbing inhabitants with a lower educational degree). Conversely intensive or conventional farming usually creates negative externalities, which cause huge damage to ecological features of systems (soil erosion, water and air pollution, reduced biodiversity and impoverished landscape). Such negative effects are commonly generated by inaccurate and inordinate use of pesticides and fertilizers. Vaznonis (2009) emphasizes that in Lithuania during the Soviet period, intensive melioration destroyed natural meadows and

Table1

Classification of agricultural externalities

Positive externalities	Negative externalities
Cultural	
The landscape itself (good/goods) Enhanced cultural landscape, geographical identity Sense of place, heritage, leisure, recreational and tourism	Impoverished landscape Damaged geographical identity Devastated heritage
Environmental	
Viable ecosystems Biodiversity and its preservation Water quality and water availability Soil quality, air quality Climate stability Resilience to fire, resilience to flooding	Damage for populations of flora and fauna Damaged soil, biodiversity loss, soil erosion Water, air pollution, gas emissions Destruction of protected objects of nature Polluted environment from different chemical nutrients, fertilizes
Social	
Maintenance of rural viability and other Employment of rural inhabitants Food security and safety Stable income, cultural heritage	Destruction of cultural objects Food insecurity
Other	
Welfare of inhabitants, livestock welfare	Human health problems caused by agricultural activity, noise

pastures, lots of wetlands, destroyed farms, lots of rivers converted to canals etc. All these consequences impoverished Lithuanian landscape, recreational potential, and decreased biodiversity.

Finally, it should be noted that agriculture, by its primary function of production of marketable goods and services, creates externalities in the form of uncompensated damage or benefit to third parties not related to that activity. Extensive farming provides public goods for the society, while intensive farming usually stipulates creation of negative externalities.

2. Valuation of agricultural externalities

The need of valuation of externalities, i.e. the calculation of benefit or the cost received occurs at two levels. At first, when political strategies are created. In this case all cost, including costs of externalities, are determined. These calculations provide information for policy creators. The analysis of externalities lets identify where the need of intervention is. On the second level, policies, programs and projects are being created or the effectiveness of the policy is analysed. In this case estimates of social costs and benefits, in the form of cost-benefit or cost-effectiveness studies, can help in decision making which agri-environmental schemes are best suited to reducing externalities or providing positive externalities.

Methods of environmental evaluation are applied generally for determination of the value (benefit or loss/cost) of non-marketable goods and services of a farming system. Scientists in environmental and natural resources economics have developed these methods specifically for assessment of non-marketable value of ecosystem goods and services. Some of them focus on the determination of consumer benefit, others on producer benefits, but the rest on calculation of the cost received.

Externalities which appear as agricultural public goods (i.e. positive externalities) are being evaluated inquiring stated preference, revealed preference; pricing and benefit transfer methods (table 2).

The evaluation of agricultural and agri-environmental policies designed to improve the provision of environmental public goods and positive externalities (or to reduce negative externalities) must account for the changes in the well-being of the benefited individuals. Therefore, stated preference valuation methods are used most often for the estimation of the benefits of agriculture goods provided for consumers. Contingent valuation and choice modelling are methods for the determination of the value of environmental goods. Both methods make use of hypothetical markets based upon carefully designed questionnaires, which are used to know the individual's willingness to pay to obtain (or to avoid), for instance, an improvement (or a decrease) in the state of a particular externality, or a set of them. These questionnaires comprise the description of the good or service to be valued, as well as the description of the transaction that is proposed to the individual in the hypothetical market. The main difference between these valuation methods relies on the way those descriptions are made (Madureira et al., 2013).

Therefore, stated preference methods are the only way to collect information about consumers' willingness to pay or get a compensation for the

Table2

Valuation methods of positive externalities

Evaluation methods	Subject of valuation	Application
Stated preference methods		
Contingent valuation Kubíčková (2004) Yrjola and Kola (2004)	Determination of the amount of money the respondent is willingness to pay for support/maintenance of certain public goods	All values of public goods
Choice modelling Jianjun et al. (2013) Grammatikopoulou et al. (2012)	Determination of the value of public goods by using respondents' choice to maintain certain environmental instruments	All values of public goods
Revealed preference methods		
Travel cost Heal (2000)	Determination of the repondents' travel price to get to the recreational place by evaluating their alternative cost	Recreational benefit
Hedonic pricing Vanslembrouck et al. (2005) Le Goffe (2000)	Determination of public goods' value by using the differences of the prices of the real property/estate where these public goods are provided and where are not.	air quality, landscape beauty, cultural values
Benefit transfer methods		
Unit value transfer Brouwer (2000)	Determination of the benefits of other localities and goods of ecosystems provided through the market and not through the market	All values of public goods
Benefit function transfer Brouwer and Spaninks (1999)		
Meta-Analysis Randall et al. (2008)		

reduction of the provision of public goods. They are based on demand - site evaluation of non-marketable goods and services, which includes non-use values. They allow for a much larger flexibility in designing valuation models that fit better the policy evaluation needs of complex, multidimensional policies such as those concerned with externalities of agricultural activity. However, the main limitation of these methods is the nature of hypothetical markets, because respondents could over- or underestimate the value of the goods, which causes the wrong interpretation of the research results.

Revealed preference valuation methods refer to the topical behaviour of respondents, which was determined by sensing. However, when applying these methods it is impossible to calculate the non-use values of agricultural goods. Travel cost refers to determination of the travel cost for the visit to the ecosystem and shows the relation between the frequency of the visits by inhabitants to the ecosystem and travel distances. By this method it is possible to determine the value of recreational goods as well as other values specific to this locality. The number of visitors and travel costs show the demand for forest locality and allows calculating the consumer benefit value provided by the ecosystem. Hedonic pricing method is usually used for the assessment of aesthetic or other qualitative features such as air quality, landscape beauty and cultural values. As Freeman (1993) has noted, this hedonic method is used for determination of the benefits of environmental goods, directly influenced by the market price.

It should be noted that revealed preference valuation methods are quite limited, because on the one part they are suitable for the determination of the use value, on the other part they could be applied for goods users only. For example, different externalities involve diverse groups of users, e.g. the use of cultural landscape for recreation involves the visitor population, whereas water availability and quality affects domestic consumers (the resident population of the watershed).

With the lack of information on particular localities, the benefit transfer methods, which refer to the evaluation of the benefits of other localities and goods of ecosystems provided through the market and not through the market, can be applied. There are three following methods: unit value, benefit function transfer and Meta-analysis methods. Benefit transfer methods are defined as the least reliable valuation type in scientific literature (Arigoni Ortiz and Serôa da Motta, 2002), because the willingness of the inhabitants from different localities to pay usually differs; moreover, the differences of the salaries of inhabitants from different localities are not taken into consideration, and the level of income differs not only on the national, but also on the regional level.

Cost calculation is used for determination of the value of positive and negative externalities. Cost methods are commonly used for evaluation of

Table 3

Valuation cost methods of externalities

Evaluation methods	Aim of evaluation
Opportunity costs Krumalova (2002)	Evaluation of possible cost or income loss due to implementation of agri-environmental schemes. The value of the positive externality estimated as an income loss from lower production intensity in comparison with intensive farming in average.
Prevention costs Krumalova (2002) Pretty et al. (2000) Tegtmeier and Duffy (2004)	Those incurred to clean up the environment and restore human health to comply with legislation or to return these to an undamaged state.
Restoration costs Krumalova (2002)	Determination of the price which was paid for the changes or improvement of providing public goods damaged ecosystem.
Administration and monitoring costs Pretty et al. (2000) Tegtmeier and Duffy (2004)	Those incurred by public authorities and agencies for monitoring environmental, food and health parameters.

environmental goods and services by determination of the farmers' damage or income loss caused by sustainable farming. Assessing the value of negative externalities the damage for environment and human health caused by agricultural activity is being calculated (Pretty et al., 2001; Tegtmeier and Duffy, 2004).

Krumalova (2002*)* assessing the value of positive externalities, i.e. enhancement of biodiversity, the maintenance of nutrient balance and genetic resources calculated 3 types of costs: opportunity, prevention and restoration cost of farming. The opportunity costs were calculated as income loss from lower production intensity in comparison with intensive farming; prevention costs as farming income, which would be lost by ensuring some benefits as pollution prevention by exclusion of fertilizers and pesticides; restoration cost as future expenditure for renewal of degraded meadows and pastures. Scientists (Pretty et al., 2000) notice that calculation of such „future" costs gives a lot of uncertainties, therefore to avoid these difficulties of evaluation they suggest calculating only the financial costs of agriculture.

Pretty et al., 2000 assessing the total external costs of UK agriculture have estimated two types of damage costs: treatment or prevention costs (those incurred to clean up the environment and restore human health to comply with legislation or to return these to an undamaged state); administration and monitoring the costs (those incurred by public authorities and agencies for monitoring environmental, food and health parameters).They have included external costs only, (i.e. the costs incurred by the rest of society for the actions by farmers) disassociating from additional private costs borne by farmers themselves, such as from increased pest or weed resistance from pesticide overuse, or for training in pesticide use, storage and disposal. Therefore, the authors have estimated only the externalities that cause financial costs. Based on the methods applied by Pretty et al. (2000), another study was carried out to estimate monetary values of external costs of agricultural and dairy production in the United States. Tegtmeier and Duffy (2004) estimated external cost per cropland. The authors calculated technical externalities with public good features.

Cost calculation helps avoiding gaps in valuation comparing with, for example, willingness to pay for public goods principle. First, this limits a part of determinants that make valuation difficult; second, it helps to avoid uncertainties related to arising cost in a specific situation in agriculture. This method does not allow determining the value of externality, as it evaluates the social cost of the specific externality only. However, estimation of external cost is a very complicated process, requiring lots of diverse statistical information from various institutions, which is very difficult to obtain.

Krumalova (2002) emphasizes that evaluating externalities invoking different methods (for example, the landscape by contingent valuation, other by replacement cost and etc.) it would not be appropriate to sum all values to one indicator. First, the value of externalities could be deputized or be to a part of other externality, second, the value of the benefit or damage of the same externality could differ subject to the methods invoked. In this case, the aim of one indicator does not have the meaningful interpretation.

Following the review of valuation methods on agricultural public goods, it should be noted that the valuation and analysis of externalities occur on two levels. On the first level, by invoking different valuation methods, as environmental evaluation and cost calculation, the cost or benefit is estimated, which

could be used for developing policy strategies. On the second level, policies, programs and projects are being created or the effectiveness of the policy is analysed in the context of integrated externalities.

The stated preference methods are commonly used for determination of positive externalities, i.e. contingent valuation and choice modelling in scientific research. The main reason for choosing this group of methods is estimation of all values of public goods. The most limited methods are travel cost and hedonic pricing methods, which are suitable only for the evaluation of public goods related to recreation or leisure. For evaluation of negative externalities, external costs of agricultural activity are calculated after defining the types of costs and disassociating them from certain factors. Estimation of external cost is a very complicated process, requiring lots of diverse statistical information from various institutions. Therefore, cost-based measures, which include other approaches, like the restoration or replacement costs, should not be used to measure positive externalities because they do not reveal any link with the individuals' preferences for these benefits.

Conclusions

1. Agriculture, by its primary function of production of marketable goods and services, creates externalities in the form of uncompensated damage or benefit to third parties not related to that activity. Extensive farming provides public goods for the society, while intensive farming usually stipulates creation of negative externalities.
2. Externalities which assert as agricultural public goods are being evaluated invoking stated preference, revealed preference and benefit transfer methods, where the main information source is consumers' questionnaire.
3. Stated preference methods are commonly used for determination of positive externalities, i.e. contingent valuation and choice modelling. The main reason for choosing this group of methods is estimation of all values of public goods. The most limited methods are travel cost and hedonic pricing methods, which are suitable only for the evaluation of public goods related to recreation, or leisure.
4. Cost calculation helps avoiding gaps in valuation comparing with, for example, willingness to pay for public goods principle. First, this limits a part of determinants that make valuation difficult; second, it helps to avoid uncertainties related to arising cost in a specific situation in agriculture.
5. Cost methods do not allow determining the value of externality, as it evaluates the social cost of the specific externality only. However, estimation of external cost is a very complicated process, requiring lots of diverse statistical information from various institutions, which is not easily available.

References

1. Arigoni Ortiz R., Serôa da Motta R. (2002) Integrated environmental strategies project for Brazil. The Economic Impact of Proconve on air pollution health effects in São Paulo, Brazil: a benefit transfer exercise. Rio de Janeiro. 48 p.
2. Beaufoy G., Baldock D., Clark J. (1994) *The nature of farming: low intensity farming systems in nine European countries*. IEEP. London, UK, 68 p.
3. Brouwer R. (1998) Future Research Priorities for Valid and Reliable Environmental Value Transfer CSERGE Working Paper, London. Available at: http://prototype2010.cserge.webapp3.uea.ac.uk/sites/default/files/gec_1998_28.pdf, 15 June 2012.
4. Brouwer R. (2000) Environmental Value Transfer: State of the Art and Future Prospects, *Ecological Economics* 32, pp. 137 – 152.
5. Brouwer R., Spaninks F.A. (1999) The validity of environmental benefits transfer: Further empirical testing. *Environmental and Resource Economics* 14, pp. 95 – 117.
6. Elbersen B.S., Andersen E. (2008) Low-input farming systems: Their general characteristics, identification and quantification. *Low Input Farming Systems: an Opportunity to Develop Sustainable Agriculture. Proceedings of the JRC Summer University Ranco*, 2-5 July 2007. pp. 12 – 21.
7. Freeman A.M. (1993) *The measurement of Environmental and Resource Value: Theory and methods. Resources for the Future*, Washington, DC. 494 p.
8. Gómez Sal A., González García A. (2007) A comprehensive assessment of multifunctional agricultural land-use systems in Spain using a multi-dimensional evaluative model. Agriculture, *Ecosystems and Environment 120*, pp. 82 – 91.
9. Grammatikopouloua I., Poutaa E., Salmiovirtab M., Soini K. (2012) Heterogeneous preferences for agricultural landscape improvements in southern Finland. *Landscape and Urban Planning,* 107, pp. 181 – 191.

10. Hartridge O., Pearce D. (2001) Is UK Agriculture Sustainable? Environmentally Adjusted Economic Accounts for UK Agriculture. Available at: www.cserge.ucl.ac.uk/AGNNP.FINALFINAL.pdf, 15 January 2014.
11. Heal G. (2000) Valuing ecosystem services, *Ecosystems*, 3, pp. 24 – 30.
12. Jianjun J., Chong J., Thuy T.D., Lun L. (2013) Public preferences for cultivated land protection in Wenling City, China: A choice experiment study. *Land Use Policy,* 30, pp. 337 – 343.
13. Krumalova V. (2002) Evaluation of chosen benefits on environment and landscape coming from Czech agriculture // *Agricultural Economics*, 48, pp. 13 – 17.
14. Kubičkova S. (2004) Non-market evaluation of landscape function of agriculture in the PLA White Carpathians. *Agricultural Economics*, 50, pp. 388 – 393.
15. Le Goffe P. (2000) Hedonic Pricing of Agriculture and Forestry Externalities. *Journal Environmental and Resource Economics* 15, pp. 397 – 401.
16. Madureira L., Santos J.L., Ferreira A., Guimarães H. (2013) Feasibility study on the valuation of public goods and externalities in EU Agriculture. JRC scientific and policy reports. Luxembourg: Publications Office of the European Union, 286 p.
17. Nemecek T., Huguenin O., Dubois D., Gaillard G. (2008) Life cycle assessment of low-input farming systems. In Proceedings of the JRC Summer University Ranco. *Low Input Farming Systems: an Opportunity to Develop Sustainable Agriculture.* Office for Official Publications of the European Communities, Luxembourg, pp. 22 – 27.
18. Pacini C., Wossinka A., Giesena G., Vazzanac C., Huirnea R. (2003) Evaluation of sustainability of organic, integrated and conventional farming systems: a farm and field-scale analysis. *Agriculture, Ecosystems and Environment,* 95, pp. 273 – 288.
19. Pimentel D., Harvey C., Resosudarmo P., Sinclair K., Kurz D., McNair M., Crist S., Shpritz L., Fitton L., Saffouri R., Blair R. (1995) Environmental and economic costs of soil erosion and conservation benefits. *Science* 267, pp. 1117 – 1123.
20. Poux X. (2008) Low input farming systems in europe: what is at stake? In Proceedings of the JRC Summer University Ranco. *Low Input Farming Systems: an Opportunity to Develop Sustainable Agriculture.*Office for Official Publications of the European Communities, Luxembourg, pp. 1 – 11.
21. Pretty J., Brett C., Gee D., Hine R., Mason C., Morison J., Rayment M., van der Bijl G., Dobbs T. (2001) Policy and practice: Policy Challenges and Priorities for Internalizing the Externalities of Modern Agriculture. *Journal of Environmental Planning and Management*, 44(2), pp. 263 – 283.
22. Pretty J.N., Brett C., Gee D., Hine R.E., Mason C.F., Morison J.I.L., Raven H., Rayment M.D., van der Bijl G. (2000) An assessment of the total external costs of UK agriculture. *Agricultural Systems* 65. pp. 113 – 136.
23. Randall A., Kidder A., Chen D. (2008) Meta Analysis for Benefits Transfer – Toward Value Estimates for Some Outputs of Multifunctional Agriculture. Available at: http://ageconsearch.umn.edu/bitstream/43648/2/013.pdf, 15 January 2014.
24. Ribaudo M., Horan R., Smith M. (1999) *Economics of Water Quality Protection from Nonpoint Sources: Theory and Practice*. Agricultural Economic Report 782. Economic Research Service, US. 113 p.
25. Sandler T., Cornes R. (1984) Easy riders, joint production and public goods. *The Economic Journal*, 94, pp. 580 – 598.
26. Schmid O., Niggli U., Pfiffner L. (2008) Development of organic farming in Europe and sustainability. In Proceedings of the JRC Summer University Ranco. *Low Input Farming Systems: an Opportunity to Develop Sustainable Agriculture.* Office for Official Publications of the European Communities, Luxembourg, pp. 59 – 68.
27. Stott A.W., Milne C.E., Goddard P., Waterhouse A. (2005) Projected effect of alternative management strategies on profit and animal welfare in extensive sheep production systems in Great Britain. *Livestock Production Science* 91, pp. 161 – 171.
28. Szabó Z. (2010) Evaluation of environmental impacts of crop production,with particular focus on biodiversity External impacts of an intensive farm and an ecological farm. Ph.D. dissertation. Budapest, 234 p.
29. Tegtmeier E.M., Duffy M.D. (2004) External costs of agricultural production in the United States. *Journal of Agricultural Sustainability*, 2(1), pp. 1 – 20.
30. Vanslembrouck I., Van Huylenbroeck G., Van Meensel J. (2005) Impact of Agriculture on Rural Tourism: A Hedonic Pricing Approach. *Journal of Agricultural Economics*, 56 (1). pp. 17 – 30.

31. Vaznonis B. (2009) Žemės ūkio viešųjų gėrybių teikimo reguliavimas ekonominės vertės pagrindu. (Regulation of agricultural public goods provision on the basis of economic value). Daktaro disertacija. Kaunas, 209 p. (in Lithuanian).
32. Viaux P. (2008) Integrated farming systems: a form of low input farming. In Proceedings of the JRC Summer University Ranco. *Low Input Farming Systems: an Opportunity to Develop Sustainable Agriculture.* Office for Official Publications of the European Communities, Luxembourg, pp. 39 – 45.
33. Vickery J.A., Bradbury R.B., Henderson I.G., Eaton M.A., Grice P.V. (2004) The role of agri-environment schemes and farm management practices in reversing the decline of farmland birds in England. *Biological conservation* 119, pp. 19 – 39.
34. Yrjola T., Kola J. (2004) Consumer Preferences Regarding Multifunctional Agriculture. *International Food and Agribusiness Management Review*, 7 (1), 34. p.

FARM DIVERSIFICATION IN HUNGARY

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Abstract
The value of farm diversification is unquestionable especially in terms of additional income generation, income stability and easing the employment difficulties of agricultural producers; its importance has recently been in the focus of agricultural and rural policies. The research purpose was to describe the situation of farm diversification in Hungary and to analyse the characteristics of diversified farms, as well as to determine which factors influence the extent and direction of diversification. The research method is based on statistical data analysing and questionnaire survey. Contrary to the above my analyses showed that the share of diversified farms is rather low in the small-scale, semi-commercial and part-time farms; its wide scale distribution is hindered by several factors. Based on the analyses I found that in private farms and in corporate farms it is characteristic that farm diversification activities are closely connected to the main activity of the farm, but they are of different type. I could state that the share of diversified farms is more significant in the labour-intensive farms and primarily in commercial farms. The share of young farmers and farmers in active age, qualified and with a full-time job is higher in the diversified and organic farms.
Key words: farm diversification, private farm, non-agricultural activities, farm structure survey.

Introduction

The most important characteristic of agricultural production is its seasonality, determined by biological parameters; this means that – mainly in crop production – peak and off-peak seasons alternate. In the off-peak periods agricultural producers try to supplement their income by off-farm activities, and by making use of their labour and machinery capacities. The income gained from agricultural production is low except in intensive horticulture. In the small - and medium-size farms agricultural production cannot provide sufficient income for the subsistence of a family. In Western Europe agricultural production is ensured mainly by family farms; half of the farms are part-time farms and a great number of farmers are engaged in diversified activities by using the resources of the farm.

This 'supplementary' or other gainful activity has always been characteristic of agriculture; however, the type and conditions varied not only in Western Europe but also in the Hungarian agriculture (Buday-Sántha, 2001). Before the political and economic transition of Hungary, i.e., in the 'prosperous' period of Hungarian agriculture (from 1968 to the mid-1980s) in cooperatives and state farms, the off-farm activities – the so-called 'secondary activities' – were widespread, ensuring the balanced utilisation of labour and other resources, and also the survival of the farms (Dorgai et al., 1989; Harcsa et al., 1994). These activities were terminated or separated from the agricultural cooperatives before the political and economic transition due to the restructuring of the large-scale and state farms, and thereby the structure of agricultural production was simplified. In the 1990s a large number of private farmers with small areas of agricultural land had to face the fact that it was almost impossible to make a living by farming.

With the EU accession, Hungary became part of the Common Agricultural Policy (CAP), which in recent decades has undergone significant changes. In accordance with the expectations of society, agriculture has to meet the requirements of sustainability, including landscape protection, safeguarding natural resources and biodiversity as well as food safety. Multifunctional agriculture, public goods, the diversity of the rural economy and improving the quality of life of rural areas are more and more emphasised (Szakál, 2000). In this context, in the CAP and among rural development professionals an increasingly accepted opinion is that farm diversification is important in retaining the rural population, expanding local employment opportunities, as well as in safeguarding and maintaining the traditional rural landscape (Fehér, 2005; Laki, 2005; Kopasz, 2005; Barghouti et al., 2004). However, the question arises whether this solution is a real option for increasing the income of agricultural producers.

Various definitions of farm diversification can be found in the literature (Griffiths, 1987; Elek, 1994; Ilbery et al., 1996; Delago-Siamwalla, 1997; Nawaratne et al., 2001; McNamara and Weis, 2001; Szakál, 2000; Boulay, 2002; Fehér, 2005). In my paper the definition of farm diversification is as follows: any gainful activity which does not involve any conventional farm work (arable farming, animal husbandry, horticulture and plantations) but is directly related to the resources or products of the farm.

In my paper I determined four specific objectives. The primary objective is to describe the situation of farm diversification in Hungary, its prevalence and importance. My second objective is to describe the diversification activities, and analyse the characteristics of diversified farms. The third objective is to examine the regional characteristics of farm diversification, as

well as to determine which factors influence the extent and direction of diversification, i.e. what are the main motivating and hindering factors.

In accordance with the research objectives I attempted to justify the following hypotheses:

- H1: Diversification is relatively closely related to the main activity of the farm.
- H2: The proportion of diversified farms is higher than average in the larger and labour intensive farms, which are commercial farms and are managed by qualified managers.
- H3: Regional characteristics and differences can be seen in the distribution of farm diversification and in the diversified activities.
-

Materials and Methods

In order to confirm (or reject) the above hypotheses, I analysed the information and databases by appropriate methods. The primary database was compiled on the basis of personal and telephone interviews. With the help of the interviews my primary aim was to determine the subjective factors influencing diversification (motivation and constraints). For the interviews I selected producers whose farms received subsidies for diversification in the framework of the subsidy schemes SAPARD and AVOP, and their projects had already been implemented. From the 20 farmers queried, 11 applied for SAPARD and nine for AVOP subsidies. The secondary database was generated from various sources:

- national and international literature,
- the relevant Hungarian and EU legislation,
- agricultural and rural development documents dated before and after the Accession of Hungary: SAPARD Plan of Hungary (2002 – 2004), Agricultural and Rural Development Operative Programme 2004 – 2006 (AVOP) and its Programme Complementary Document (AVOP-PKD), New Hungary Rural Development Plan 2007 – 2013 (ÚMVP),
- agricultural and rural development programmes (SAPARD, AVOP, ÚMVP) annual implementation reports, mid-term and ex-post evaluations,
- the Farm Structure Survey (FSS) of 2003, 2005, 2007, the databases of Eurostat,
- Hungarian Central Statistical Office (KSH): Agricultural Census 2000, and 2010. Farm Structure Survey in Hungary 2003, 2005, 2007 database,
- data on the subsidies of the Agricultural and Rural Development Agency (SAPARD, AVOP and ÚMVP).

I processed the data with the aim of revealing the prevalence and role of diversification and to present the main activities of diversification, and furthermore, to determine the objective factors of diversification. It is not possible to analyse the economic importance of non-agricultural activities of the farms on the basis of the FSS since it does not provide any data on the production value or the income generated by these activities. The Farm Accountancy Data Network (FADN) data are not suitable for analysing the economic importance of diversified activities either because of the small number of samples. Therefore, my analysis can show only the presence of these activities. The methods applied are: calculation of average, proportion, statistical distribution, function in time (change in time). For calculating and preparing the tables and diagrams I used Microsoft Excel 2003. These calculations were suitable for analysing, confirming or rejecting the hypotheses described above.

Results and Discussions

Extent and characteristics of on-farm diversification

On the basis of the FSS (2003, 2005, 2007) only 5%, in 2010 8% of total farms, were engaged in any kind of gainful activity connected to the farm but other than the main agricultural activity of the farm. In accordance with the methodology of the survey, diversified activities are all kinds of non-agricultural activities which are connected to the resources of the farm (for example, labour, agricultural area, machinery, building) or to the processing of farm products. These activities cover the services and the production of farm products marketed partially or in total by generating additional income. The survey did not cover the activities of providing services or products for their own consumption. In the 28 Member States of the EU the share of diversified farms accounts for 5.2% on average in 2010. Diversification is more frequent in corporate farms than in private farms. About 40% of the corporate farms were engaged in any kind of activity besides the main activity, but in private farms the percentage was only 6% in 2010.

Between 2003 – 2007 the number of diversified farms of both legal forms fluctuated in line with the total number of farms. In accordance with this, the number of corporate farms increased while those of private farms decreased. After 2007 the number of diversified private farms became increased by 20%. The percentage of diversified farms in total increased to a small extent due to the concentration of farm structures (Table 1).

I analysed the regional characteristics and the differences of farm diversification on the basis of FSS data. As a result of the analysis, I stated that regional differences in farm diversification can be seen. The share of diversified private farms was the highest (9.3%) in 2010 in the Northern Hungary Region, which regarding the employment was in the most

Table 1

The number of diversified farms 2003 – 2010

	2003	2005	2007	2010
Corporate farms, total	7813	7927	7405	8606
Diversified corporate farms	1502	2562	2651	3336
Share of diversified corporate farms %	19.2	32.3	35.8	38.8
Private farms, total	765608	706877	626056	567446
Diversified private farms	33679	33592	29175	34818
Share of diversified private farms %	4.4	4.8	4.7	6.1

Source: HCSO: Farm Structure Survey in Hungary 2003, 2007, 2010.

unfavourable situation. In the Central Transdanubian Region the share of diversified private farms was also high (9.1%). This can be explained by the more favourable market demand due to the proximity of the capital. In the case of corporate farms the share was higher than the national average in the two regions of the Great Plain and the Southern Transdanubian Region. In these regions arable farming is characteristic; consequently, in the corporate farms the conditions are more favourable for machinery services.

Regional differences can be seen in the popularity of the various diversified activities and in their distribution. This is in close connection with the production structure and the characteristics of the given region. Therefore, in the regions of the Great Hungarian Plain – where arable farming is dominant – the share of diversified farms is high among corporate farms, which provide mainly machinery contracting services. By contrast, in Northern Hungary, where due to the natural conditions and production traditions the share of fruit farms and vineyards is higher than the national average a very high proportion of individual farms is engaged in processing farm products.

Concerning the main diversified activities and the characteristics of the farms, the corporate farms try to make use of their machinery and equipment through contracting (machinery servicing, transport and delivery), and their diversification is based mainly on their equipment and machinery capacities. A significant share of them are also engaged in commerce (Figure 1). Individual farms, however, try to diversify their activities via food processing, which assists the more balanced use of their labour capacity. Most farms increase the scale of their activities by fruit, vegetable and meat processing, and wine making.

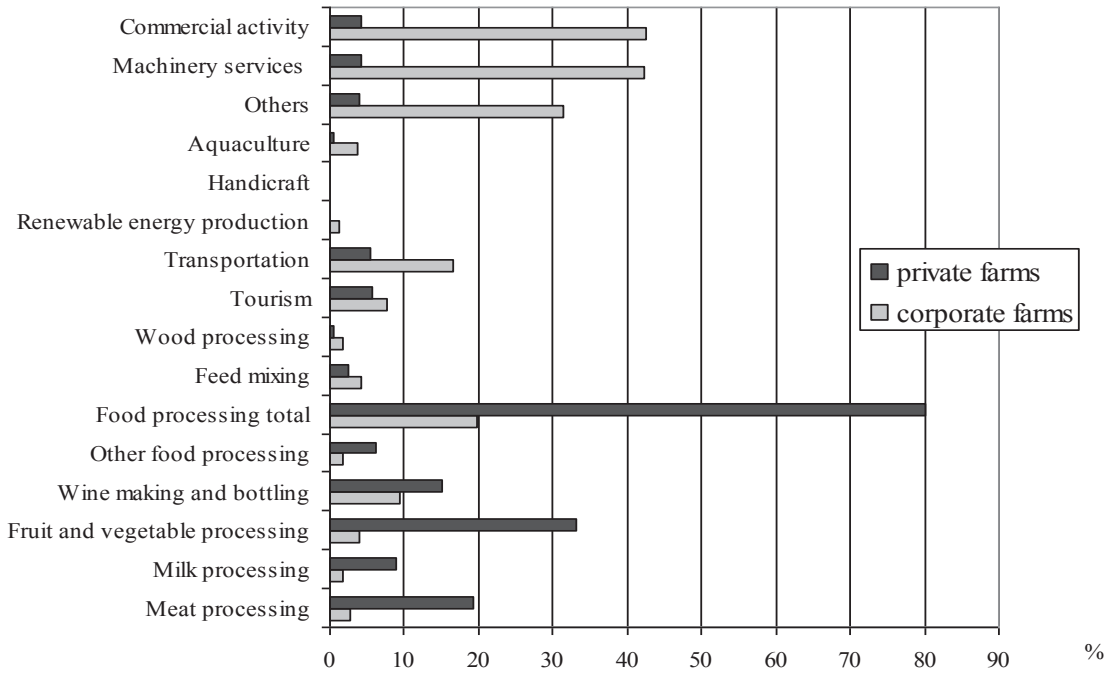

Figure 1. Distribution of diversified farms by activities, 2010.

Source: HCSO: Agricultural Census 2010.

Between 2000 and 2010 the extent and direction of the change varies significantly by activity. For example, the number of milk processing farms of both legal forms increased, in private farms it doubled and the number of corporate farms increased by 50%. The number of meat processing farms of both legal forms increased up to 2005 and then it decreased, and the extent of the decrease was larger in the case of corporate farms than those of private farms starting to stagnate. In line with the increase of the number of farms producing animal products the number of husbandry farms decreased continuously. I concluded that in this process the number of animal husbandry farms decreased due to the continuous winding up of semi-subsistence and subsistence farms, but the large farms with capital supply tried to survive by increasing the value added and the level of processing. The number of fruit and vegetable processing private farms increased significantly, - by fivefold during this period, - while the number of corporate farms decreased. The changes in the number of fruit and vegetable processing farms are due to the same reasons as in husbandry farms since the number of fruit producing farms decreased by one third and those of vegetable producing farms by half during the same period.

The number of farms engaged in wine making and bottling decreased drastically after 2000, which is probably due to the amendment of the act on excise tax published at the end of 1999 and enforced from 1 August 2000. In accordance with the amendment, the act at present applies also to wine. The share of farms engaged in catering is low; however, it is promising that the number of private farms engaged in this activity has been increasing since 2000. The increase was especially significant between 2005 and 2007. This might be due to the governmental decree on rural and agrotourism[1], in accordance with the decree, the rural hosts may sell their own products locally, in their guest house. In addition to this, the increase of the limit of tax free income generated by rural tourism from HUF 400 to 800 thousand had also a favourable effect.

Renewable energy production is getting more and more popular, probably due to the support schemes; more and more farms choose this kind of diversification.

Analysis of the factors influencing diversification

Farm diversification is a consequence of numerous factors, e.g. the size of the farm, the production line and production aim, the qualification level of farm managers. For the examination of these factors the latest accessible data source is FSS 2007. On the basis of the analysis I concluded that parallel to the increasing size (economic size and utilised agricultural area) and the labour used, the share of diversified farms is also increasing (Hamza, 2011).

The production line determines also if a farm diversifies its activity and in which direction. I analysed the share of diversified farms in the various production lines. I concluded that diversification can be found in more than half of mixed corporate farms, and 41 – 43% of arable farms and specialist horticulture farms are diversified farms (Figure 2). It is well known that the diversification of corporate farms means mainly machinery services, transportation and commerce as well as wine making; therefore, it is not surprising that among crop producers the share of diversified farms is high.

Amongst private farms the share of diversified farms of plantations and grazing livestock accounts

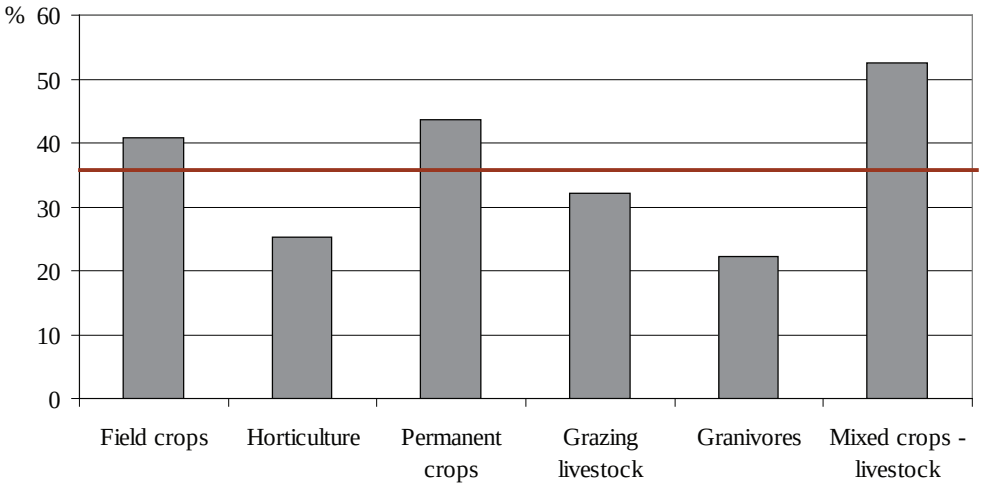

Figure 2. Sharing of diversified corporate farms in different production lines.

Source: HCSO: Farm Structure Survey in Hungary 2007.

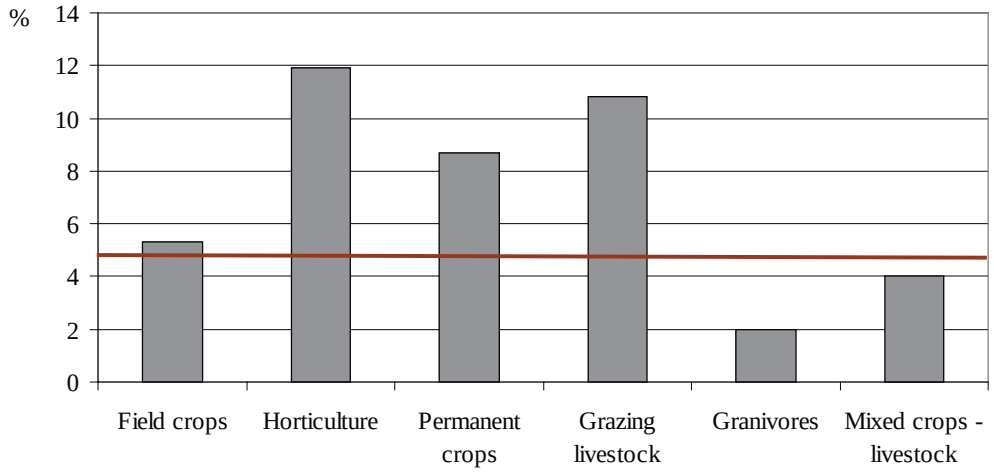

Figure 3. Sharing of diversified private farms in different production lines.
Source: HCSO: Farm Structure Survey in Hungary 2007.

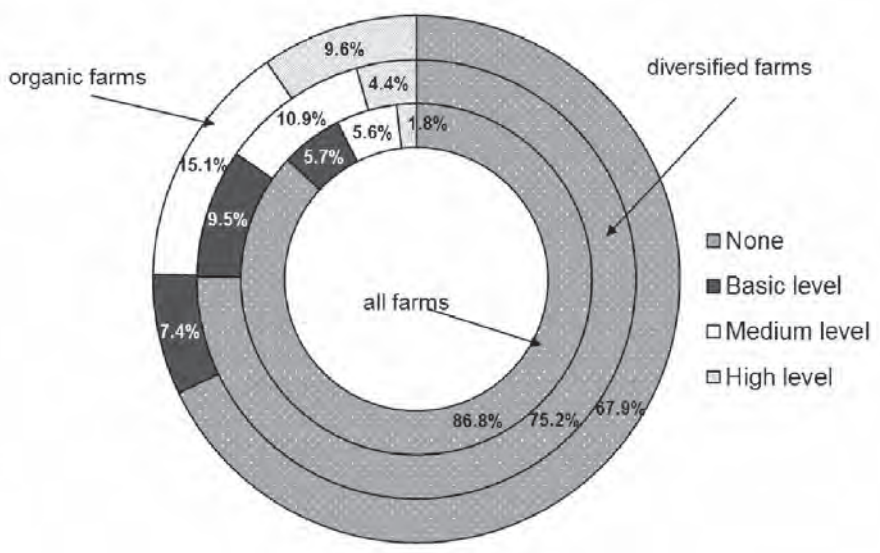

Figure 4. Distribution of farm managers by qualifications, 2007.
Source: HCSO: Farm Structure Survey in Hungary 2007.

for about double (9% and 11%, respectively), while amongst granivores and mixed farms the diversified farms are underrepresented. The majority of private farms (82%) are engaged in food processing; i.e., fruit processing and wine making, which are obviously characteristic for specialist farms of orchards and horticulture. The meat and milk processing are also common confirming the high share of farms with grazing livestock (Figure 3).

With my analysis I managed to show that among both diversified farms and organic farms the share of commercial farms (marketing more than 50% of the products) accounts for a higher rate – i.e., for about the double of the average – than in total farms.

Only slightly more than one fifth (22%) of the farm managers queried answered that their income is generated mainly by the farm. In the case of diversified farms this share accounts for 37% and of organic farms for 46% indicating that regarding income generation the diversified farms, which produce higher value added, are in a more favourable position. Among the diversified and organic farmers the share of farmers who are of active age and qualified as well as those whose main income source is the farm account for a larger than average share.

The relationship between diversification and qualification/skills is outstanding and is also a warning. The share of managers with medium or

higher qualification is two or three fold in diversified and organic farms than in total farms (Figure 4). This indicates that farms managed by competence and skills are successful and this might provide a base for Hungarian agriculture and the development of the rural economy.

By analysing the statistical data the results obtained revealed several factors which determine the conditions of the farm and have an impact on diversification (on its extent and direction). However, there are factors which play a role in the decision making of launching diversification or not, but which are not measurable statistically. These can only be surveyed by empirical methods, with the help of personal interviews with the farmers and their family members. On the one hand, there are external factors originating from the environment of the farm, such as the factors determining the market demand, subsidy schemes, competitors, infrastructure, but on the other hand, the endogenous factors inherent in the conditions and resources of the farms are also significant In the interviews I asked them about the motivation and constraints, which played a role in launching and implementing the diversification.

My empirical survey justified the statement published in the literature that the most important incentives for farm diversification are the higher income and the use of surplus resources. One third of the respondents considered diversification successful and their development plans were also promising.

Most farmers queried mentioned the lacking or fluctuating purchasing power as the most important constraint. Among the endogenous constraints the first is the lack of capital mentioned by almost all respondents. The success of the diversified activity, based on the unanimous opinion of the respondents, depends mainly on the market demand; however, the information, skills, risk taking and entrepreneurial behaviour of the farmers also play important roles. In view of the fact that the market demand and the marketable product or service are the most important factors, it is not surprising that in the plans of the farmers surveyed the developments assisting the market access and increasing the value added are the most often mentioned (Hamza, 2011).

Results of subsidies of diversification; assessment of the gained experience

Subsidies for diversification and for alternative gainful activities can be found in the Hungarian agricultural and rural development programmes of the last decade (VFC, SAPARD, AVOP, ÚMVP). The amount of the subsidies provided is rather modest. In these schemes the emphasis placed on diversification has not increased with time. No development can be seen in the implementation of the programmes either. Therefore, the subsidies only partially reached their aims and consequently the number of diversified farms did not increase significantly. In my opinion, the subsidy schemes do not approach the question in an integrated way and do not adjust to the demands of the target group. The subsidies did not come up to the expectations due to several reasons:

- The budget provided for one project is rather small (in SAPARD and AVOP the average budget of a project amounts to HUF 8 million), which is insufficient to cover the costs of the preparation of the application;
- The preparation of the application is rather complicated; therefore, the applications prepared by the tenderer him/herself did not meet the requirements;
- The rural population is not prepared to launch new activities or enterprises. The entrepreneurial behaviour, the skills and the willingness to acquire the necessary information are all lacking.
- The agricultural producers do not have sufficient information on the market demand of the products or services.

Amongst the new activities the ones related to rural accommodation and tourism are the most popular. However, we note that a significant number of agricultural producers did not make use of the opportunity provided for income diversification, since the majority of the applicants were private persons who were not engaged in agricultural production.

The regional distribution of the rural development programmes to be implemented in co-financing by the EU and Hungary for diversification indicates that most subsidies were awarded to the counties in North-East Hungary (Borsod-Abaúj-Zemplén, Szabolcs-Szatmár-Bereg, Hajdú-Bihar counties) and to Baranya county in Southern Transdanubia. These are the regions where the share of population engaged in agriculture is the highest and the rate of unemployment is larger than the average; therefore, farm diversification in these regions is a kind of necessity for subsistence. However, these regions are in a favourable position and are suitable for certain activities (rural tourism, fruit and vegetable processing).

The amount of subsidies provided are the smallest in the western counties of a more favourable position regarding employment and in some counties of the Great Hungarian Plain where a simple production structure is characteristic (arable farming) and farm diversification is not feasible. In Pest and Fejér counties average amounts of subsidies are provided due to more favourable market demands explained by the proximity of the capital (Budapest).

Conclusions

1. The primary reason of agricultural enterprises to launch a new gainful activity is to make optimal use of the capacities available. Therefore, the available capacities determine the direction of diversification. On the basis of my analysis I showed that in corporate farms the most frequent gainful activity in addition to commercial activities is contract work (machinery services). The share of diversified farms is higher than the average in arable and mixed farms. In the majority of private farms diversification means processing of their own farm products; i.e. fruit and vegetable processing, meat processing, wine making and bottling. These food processing activities can primarily be connected to labour-intensive horticulture, orchards and animal husbandry. The percentage of diversified farms among private farms exceeds the average level in each of the above three production lines. In both legal forms the diversified activities are closely related to the main activity of the farm; therefore, my hypothesis was proved.
2. Based on the analysis of the data of the farm structure survey I could show with the help of simple statistical methods and confirm by the information gained from the literature that farm size – by considering both the economic size and utilised agricultural area – and labour utilised increase in line with the share of diversified farms increases. My analyses showed that in diversified private farms the share of managers with medium or higher qualifications and the share of commercial farms account for more than the double of the average.
3. Based on the statistical data (FSS 2007) and the data of the subsidies financed (SAPARD, AVOP, ÚMVP) I determined the regional relationships of diversification. Both databases indicate that diversification is most significant in private farms of the Northern region of Hungary, where the employment rate is the lowest and the number of entitled farms is the highest. Regarding the diversification activities, I managed to show using direct evidence that in corporate farms machinery services are most frequent in arable farms in the Great Hungarian Plain and in Southern Transdanubia; while in Northern Hungary in private farms the most popular activity of diversification is the processing of farm products. This is due to the conditions of the region and the production structure of the farms (larger than average areas of orchards, vineyards and grazing lands)

References

1. Barghouti S., Kane S., Sorby K., Mubarik A. (2004) Agricultural diversification for the poor. Guidelines for practitioners. Agricultural and rural development discussion paper 1, the Word Bank). Available at: http://lnweb18.worldbank.org/ESSD/ardext.nsf/11ByDocName/AgriculturalDiversificationforthePoorGuidelinesforPractitioners/$FILE/Diversification_Web.pdf, 20 January 2007.
2. Boulay A. (2002) An analysis of farm diversification in France and the United Kingdom based on case strudies of Sud Manche and West Dorset. Available at: http://www.kingston.ac.uk/geog/staff/abstracts/annabel, 02 April 2007.
3. Buday-Sántha A. (2001) Agrárpolitika-vidékpolitika. (Agricultural Policy - Rural Policy) Dialóg Campus Budapest-Pécs. pp. 94 – 95.
4. Delgado L.C., Siamwalla A. (1997) Rural Economy and Farm Income Diversification in Developing Countries. Markets and Structural Studies Division International Food Policy Research Institute Washington D.C., USA. Available at: http://www.ifpri.org/divs/mtid/dp/papers/dp20.pdf, 03 March 2008.
5. Dorgai L., Fehér A., Szabó M., Szepesy E. (1989) Az alaptevékenységen kívüli tevékenység szerepe a mezőgazdasági nagyüzemek életképességének fenntartásában (Borsod-Abaúj-Zemplén megye példáján). (The role of non-agricultural activities in maintenance of viability of agricultural large-scale farms / example of Borsod-Abaúj-Zemplén counties). Research Institute of Agricultural Economics, Budapest. pp. 32 – 43. (in Hungarian).
6. Elek S. (1994) Részmunkaidős farmok a fejlett országokban (Part-time farms in developed countries). Szociológiai Szemle 1994/1. pp. 115 – 125. (in Hungarian).
7. Fehér A. (2005) A vidékgazdaság és a mezőgazdaság (Rural economy and the agriculture). Budapest, Agroinform. pp. 256 – 270. (in Hungarian).
8. Griffiths A. (1987) Farmer's attitudes to diversification, Working Paper, University of Exeter.
9. Hamza E. (2011) The main relationships of diversification in agricultural enterprises. Doctoral Thesis Szent István University, Gödöllő. pp. 77 – 83.

10. Harcsa I., Kovách I., Szelényi I. (1994) A posztszocialista átalakulási válság a mezőgazdaságban és a falusi társadalomban. (Post-socialist transformation crisis in agriculture and rural society). Szociológiai Szemle 1994/3. pp. 15 – 43. (in Hungarian).
11. Ilbery B., Healey M., Higginbottom J., Noon D. (1996) Agricultural adjustment and business diversification by farm households. Geography 81 (4), pp. 301 – 310.
12. Kopasz M. (2005) Multifunkcionális mezőgazdaság az EU törekvéseinek összhangjában. (Multifunctional agriculture in the consistency of aspirations of the EU). A Falu, 1. szám pp. 51 – 60. (in Hungarian).
13. Laki G. (2005) A családi gazdaságok fenntarthatóságának kérdései (Problems of sustainability of family farms). A Falu 2005/4 pp. 5 – 17. (in Hungarian).
14. McNamara K., Weiss C. (2001) On- and Off-Farm Diversification. Paper presented at the 2001 AAEA-CAES Meeting in Chicago. p. 5. Available at: http://ageconsearch.umn.edu, 05 November 2009.
15. Nawaratne B.Y., Kodithuwakku S.S., Murray F., Little D.C. (2001) Entrepreneurial Strategies Adopted by Rural Inland Fishermen in the Dry Zone of Sri Lanka. Available at: http://www.dfid.stir.ac.uk, 03 December 2009.
16. Szakál F. (2000) A vállalat, mint gazdasági rendszer (The Company as an economic system). In: Buzás Gy., Nemessályi Zs., Székely Cs. (2000) Mezőgazdasági üzemtan I. (Agricultural economy I.). Mezőgazdasági Szaktudás Kiadó, Budapest. pp. 31 – 32. (in Hungarian).

THE CONSUMER'S CHOICE OF BRANDED PRODUCTS CONFORMITY TO NATIONAL IDENTITY: CASE OF BALTIC STATES

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Abstract
The aim of the paper is to show the general trend of consumption in the Baltic countries. The member states of the European Union attach great importance to the well-being, health and the promotion of healthy lifestyle. In order to be able to make decisions on the future plan of action, COBEREN (Consumer Behaviour Erasmus Network) carried out a project with an aim of studying the food consumption habits in the European Union countries. The obtained results show the consumer habits of each participating state, although not on the regional level. This study will look at the consumption habits in the Baltic countries and find out the nature of consumption in those three states. The statistical method – analysis of variance – was used to analyse the COBEREN data.
The main conclusion is that consumers of the Baltic countries do not differ greatly in their consumption habits.
Key words: local product, COBEREN, product brand, attention to brands.

Introduction

The European Union has drawn attention to sustainable food consumption issues and sustainable food production in an attempt to prevent the agri-food industry's excessive wastage of resources. In order to find a package of measures for food producers was necessary to ascertain the consumption habits of the population.

The knowledge of consumer behaviour is of great relevance from both the economic and civic point of view. COBEREN research provides an urgently required pool of knowledge on consumer behaviour that allows the firms, other associations and public organisations to take appropriate corporate decisions in the European market. The consumer is offered a wide choice of products – famous brand products or locally produced goods. After that consumer attitudes towards the produce of different manufacturers - locally produced products or brand manufacturers products – were identified. It was also established whether the brand is or is not an important factor influencing the choice of a product. The explanation of concepts - locally produced products and brand products - is provided in the 'Results and Discussion' section.

The authors have set the task to find out whether there are significant differences in the consumption habits in the Baltic countries. COBEREN data analysis of a cross-section of the Baltic States will examine the differences between the consumption in the Baltic countries. The article examines the following four assumptions:

there are no significant differences between the consumers of Baltic states preference for more famous brands; there are no significant differences between the attention the consumers of Baltic states pay to the product brands; there are no significant differences when the consumers of Baltic states choose locally made products; there are no significant difference between consumers of Baltic states on basis of conformity to the national identity.

Materials and Methods

The research methodology consists of two parts. The first part describes how COBEREN collected the research data. The second part describes what kinds of methods were used in the statistical analysis of COBEREN research data.

COBEREN survey

Considering the large number of participants and the heterogeneity of the group, the research methodology of COBEREN has been defined in a very specific way. Researchers have implemented a mixed methodological approach, combining qualitative and quantitative techniques and used a various range of numerical, verbal and even pictorial measurements. The scope for covering different dimensions of the consumer culture was made as open as possible but had to remain acceptable from the point of view of the survey response process.

A qualitative data collection allows capturing an in-depth description of consumption behaviour and meanings without any specific preconceived rational model. To which extent do the spontaneous evocations of the respondents match or not with some classical references regarding needs, motivations, or habits? On that basis, explanatory research can lead to the definition of inductive clusters based on consumption profiles that can be interpreted in terms of consumption style or culture sub-clusters. To which extent are they global or country-dependent? Are they affected by general attitudes and values towards consumption?

Mixing qualitative and quantitative analyses on a very large data set of 30 European countries will allow the COBEREN team members to investigate the interactions between individual features and preferences, social habits and representations, national

belonging, culture and consumption behaviour and ideology.

1. Internet surveys

The European COBEREN survey was mainly conducted through a common on-line questionnaire from January to March 2011. Final raw total sample collected by the COBEREN survey were 12,608 units. The final size of the "calibrated" sample is 5,250 units.

Researchers decided to design a common Web questionnaire that would be translated into all 23 European languages and then to disseminate the survey through various procedures, according to the more adopted options in each of the countries. Three different Internet data collection protocols were therefore implemented:

- Dissemination through the Web access panels' members in Austria, Sweden and the United Kingdom, for example. Generally speaking, that procedure was possible in the countries located in the centre and north of the continent.
- Snowball procedure, for which the link is sent to some specific target people who are successively requested to circulate the survey to other personal contacts, etc. That specific process was implemented in Greece, for example, where it was really successful.
- 'Pre-recruited' participants enrolled by students or research assistants. Those persons have agreed to give us their email address and to participate specifically in COBEREN research project. This method was successfully used in Iceland, Italy, and Romania, for example. We wrote a common invitation email mentioning the identity of the correspondents, the general objective of the study and some privacy information.

2. Face-to-face interviews

In order to complement the main data collection method and be able to reach some of the target respondents, especially in the older age categories, we agreed on conducting some face-to-face interviews, in the countries where senior people could not be easily contacted through Internet questionnaires, for example, in Lithuania or in Portugal. Printed versions of the COBEREN questionnaire were produced for that particular usage.

In most of the COBEREN partner countries where an Internet access panel was not available or not chosen (17 cases/30 countries), a multi-channel data collection method was conducted for a proper reaching of all the pre-defined targets from all the different age groups (Santos et al., 2013).

The COBEREN survey responses were used in connection with non-alcoholic drinks. The authors sought to determine whether the product users pay attention to the local product or not, the importance of local production, the importance of product brands, and whether this product is associated with the national identity.

Statistical methods

The COBEREN research database data relating to consumers' choice of products and answers on the principles of national identity were analysed by statistical methods. The studied variables were coded. A respondent, according to gender, was assigned a code 'Male' = '1', 'Female' = '2'. Respondent's answers were coded 'I totally disagree' = '1', 'I rather disagree' = '2', 'I do not know' = '3', 'I agree rather' = '4', 'I totally agree' = '5'; and A) 'Far apart' = '1', B) 'Small overlap' = ' 2', C) 'Moderate overlap' = '3', D) 'Large overlap' = '4', E) 'Complete overlap' = '5'. The authors of the study were using analysis of variance with Scheffe test to find out if there are significant differences between the groups - the Estonian, Latvian and Lithuanian consumer choice of brand product. The analysis of variance was used to test the Estonian, Latvian and Lithuanian male and female attitude to the more well-known brands, their focus on brand products, locally made product selection and compliance with national identity.

Results and Discussion

Consumer choice is not always rational. An important role is played by the product quality and visibility. Food can be recognized by its producer, production location and by the brand. Product branding has existed for centuries as a way of distinguishing items from one another, while the modern concept of branding has its roots in the 19th century. According to this concept, a brand can be perceived as a legal instrument, logo, company, system identification, character, personality, relationships, or the added significance (Konecnik et al., 2007).

Thus, consumer and brand's identification associates with a consumer and brand's unity that is true and impressive expression of our identity search (Stokburger-Saueret et al., 2012). There are several brand classifications: national brands, store brands, and discount brands (Batte et al., 2010).

A brand is a particular product visibility in the eyes of consumers. It is considered that consumers tend to buy famous brands out of habit or because of loyalty, and they may be willing to pay more for branded products than non-branded generic products when they see the positive effects of the use of the brand (Paasovaara, 2012). Brands tend to result in a significant premium, and thus their applications are

considered to promote value-added agriculture (Jin et al., 2008).

Brands were also ranked according to a three-point scale of programmed informational benefits, which was based on an analysis of brand positioning, such as good-value-for-money own brands, higher-level own and lower-level national brands, and higher-level national brands (Oliveira-Castro, 2008). Some scientists believe that the ethnic-based subcultures established agents could build community brands. A brand community is a community of people brought together by the emotional attachment to the product or brands. There is a close relationship between brands, individuals and cultures (Veloutsou et al., 2009). The literature suggests that branded products are more valuable because consumers associate them with a better performance in three key areas: quality/ reliability, design and prestige (Jin et al., 2008).

Local brands have traditionally benefited from a high level of awareness and close relationships with consumers in their countries (Özsomer, 2012).

Terms such as 'local food' and 'local food system' are often used interchangeably to refer to food produced near its point of consumption in relation to the modern or mainstream food system. The concept 'local food' has been expanded and fulfilled several political projects. The organic project has avoided co-optation. International solidarity movements have helped develop new paradigms of global consumption (Starr, 2010). Regional products and local foods are, by definition, geographical phenomena (Parrott et al., 2002). By the definition of U.S. Congress, local food is a product, which is created locally and distance that a product can be transported and still be considered a 'locally or regionally produced agricultural food product' is less than 400 miles from its origin, or within the State in which it is produced (Martinez et al., 2010). Fritz and authors found that consumers can identify local food if the distance between local food producer and consumer is less than 30 miles (Fritz et al., 2009). According to this definition, both terms – 'local food' and 'regional foods' are similar.

Results and Discussion

This section of paper consists of four parts that summarize the principles of consumption existing in the Baltic countries. The first part analysed consumer attitudes towards the more famous brand products. The second part reflects information about attention to brands. The third part looks at consumer attitudes towards locally made products. The fourth part shows consumer attitudes to national identity.

Choice of more famous brands

Consumers choose products for themselves of certain characteristics. The authors of COBEREN research wanted to determine whether the consumer chooses more famous brand products, or there is an alternative choice. The Baltic consumers choose products not only by more famous brand attributes.

Baltic states males' choice of more famous brand products

The result of analysis of variance calculation obtained - p-value = 0.270 with a significance level of $\alpha = 0.05$ - suggests that the groups have the same variance. The calculation results indicate that $p = 0.005 < \alpha = 0.05$, so the null hypothesis is rejected, the entire group averages are the same, and the adoption of alternative hypothesis - the whole group averages are different.

After comparing the three Baltic COBEREN data and performing statistical calculations, the authors have come to the conclusion that in Estonia and Lithuania, the male consumer choice of more famous brand products differs significantly. For Lithuania and

Table 1

Choice of more famous brands

Gender	Country	I totally disagree	I rather disagree	I don't know	I rather agree	I totally agree
Male	Estonia	22.7	39.8	3.4	28.4	5.7
	Latvia	20.7	26.4	3.4	40.2	9.2
	Lithuania	14.7	21.3	4.0	46.7	13.3
Female	Estonia	23.3	40.7	3.5	30.2	2.3
	Latvia	24.1	43.7	4.6	17.2	10.3
	Lithuania	25.6	17.4	2.3	41.9	12.8

Source: made by the authors, based on COBEREN research data (the percentage of respondent answers).

Estonia, the group dispersion parameter p = 0.005 < α = 0.05, and the authors adopted the alternative hypothesis that there are significant differences between the groups - Estonia and Lithuania averages.

Latvian and Estonian group variance ratio p = 0.197 > α = 0.05, so it was not rejecting the null hypothesis that there is no significant difference between the mean values of the graduation class. However, it should be noted that the Latvian and Lithuanian graduation class mean values are not significantly different - the resulting pointer p = 0.314 > α = 0.05. These results lead to the conclusion that the Estonian and Lithuanian males in connection with the selection of the more famous brand choices are more radical, but Latvian males are more moderate in their choice, compared to the neighbouring country males (Table 1).

Baltic states females' choice of more famous brand products

Results of analysis of variance results obtained p-value = 0.003 with a significance level of α = 0.05 suggests that the female group averages are different, thus rejecting the null hypothesis that all group averages are the same, and the adoption of alternative hypothesis - the whole group averages are different.

The authors have come to the conclusion that in Estonia and Lithuania the female consumer preferences related to a more famous brand products differ significantly. For Lithuania and Estonia, the group dispersion parameter p = 0.044 <α = 0.05, and the authors adopted the alternative hypothesis that there are significant differences between the groups - Estonia and Lithuania averages.

Latvian and Estonian group variance ratio p = 0.997 > α = 0.05, so it was not rejecting the null hypothesis that there is no significant difference between the mean values of the graduation class. Latvian and Lithuanian graduation class mean values have significant differences, as evidenced by the resulting pointer p = 0.035> α = 0.05. The results obtained suggest that the Estonian and Latvian females in their choice of famous brand products are similar to the Lithuanian females (Table 1).

Attention to Brands

Research of COBEREN tried to find out whether consumers pay attention to brands. Baltic consumers pay attention to brands, but most of the respondents claim that they do not pay attention to particular brands or do not pay attention to brands at all. This section explores the answer to the question whether a brand is an important factor when choosing a product.

Baltic males and attention to brands

Analysis of variance obtained p-value = 0.545 with a significance level α = 0.05 suggests that the groups have the same group averages.

The tests of analysis of variances obtained p-value = 0.545 with a significance level α = 0.05 suggests that the groups have the same variance. The calculation results indicate that p = 0.025 <α = 0.05, thus the null hypothesis that all group averages are the same is rejected, and the alternative hypothesis is adopted - the whole group averages are different.

The authors have come to the conclusion that in Estonia and Lithuania the male consumer preferences relating to the focus on brand products differ significantly. For Lithuania and Estonia, the group dispersion parameter p = 0.566> α = 0.05, and the authors adopted the null hypothesis that there is no significant difference between the groups - Estonia and Lithuania averages. Latvian and Estonian group variance ratio p = 0.026 <α = 0.05, so an alternative hypothesis was adopted that 'there is a significant difference between the mean values of the graduation class'.

However, it should be noted that the Latvian and Lithuanian graduation class mean values are without significant differences - the resulting pointer

Table 2

Consumers' Attention to Brands

Gender	Country	I totally disagree	I rather disagree	I don't know	I rather agree	I totally agree
Male	Estonia	14.8	40.9	2.3	34.1	8.0
	Latvia	11.2	22.5	3.4	48.3	14.6
	Lithuania	14.9	31.1	1.4	43.2	9.5
Female	Estonia	12.6	36.8	4.6	33.3	12.6
	Latvia	18.2	30.7	2.3	35.2	13.6
	Lithuania	30.2	24.4	1.2	34.9	9.3

Source: made by the authors, based on COBEREN research data (percentage of respondent answers).

p = 0.310 > α = 0.05. These results lead to the conclusion that the Latvian and Lithuanian males regarding the selection of the best-known brands behave similarly, but the Estonian males pay attention to brand products differently than Latvian and Lithuanian males (Table 2).

Baltic females and attention to brands

Analysis of variance results obtained p-value = 0.003 with a significance level α = 0.05 suggests that the group averages are different.

The calculation results indicate that p = 0.152> α = 0.05, so the null hypothesis is retained, the entire group averages are the same. The authors have come to the conclusion that Estonian and Lithuanian female consumer preferences related to a well-known brand products do not differ. For Lithuania and Estonia, the group dispersion parameter p = 0.418> α = 0.05, and the authors retained the null hypothesis that there is no significant difference between the female groups - Estonia and Lithuania averages.

Latvian and Estonian group variance ratio p = 0.997> α = 0.05, so it was not rejecting the null hypothesis that there is no significant difference between the mean values of the graduation class. Latvian and Lithuanian graduation class mean values have no significant differences, as evidenced by the resulting pointer p = 0.444 > α = 0.05. The results obtained suggest that in the Baltic countries, females pay attention to brand products similarly (Table 2)

Locally made products

Brand product offering has an alternative offer - locally made products. COBEREN research found what the consumer's choice is when they are prompted to buy locally made products. The consumer of Baltic countries chooses locally made products. This section examines whether the consumer prefers locally made products.

Baltic males and locally made production

Analysis of variance results obtained p-value = 0.00 with a significance level α = 0.05 suggests that the group averages are different.

The results indicate that p = 0.006 <α = 0.05, thus rejecting the null hypothesis that all group averages are the same, and the adoption of alternative hypothesis - the whole group averages are different. There were insignificant differences between Estonian and Lithuanian male consumer preferences relating to the focus on locally made products.

The Lithuanian and Estonian group class graduation parameter p = 0.151 > α = 0.05, and the authors adopted the null hypothesis that there is no significant difference between the groups - Estonia and Lithuania averages. Latvian and Estonian group variance ratio p = 0.411 > α = 0.05, so the alternative hypothesis that there is a significant difference between the mean values of the graduation class was not accepted. However, it should be noted that the Latvian and Lithuanian graduation class mean values have significant differences - the resulting pointer p = 0.006 > α = 0.05. These results lead to the conclusion that the Latvian and Lithuanian males in their the selection of locally made products are not similar, but Latvian males pay attention to locally made products differently than males in Estonia and Lithuania (Table 3).

Baltic females and locally made production

Analysis of variance result p-value = 0.04 with a significance level of α = 0.05 suggests that the group averages are different.

The calculation results indicate that p = 0.150 > α = 0.05, so the null hypothesis is retained, the entire group averages are the same. The authors have come to the conclusion that there are no differences between the Estonian and Lithuanian female consumer preferences regarding the locally made products.

Table 3

Choice of locally made products

Gender	Country	I totally disagree	I rather disagree	I don't know	I rather agree	I totally agree
Male	Estonia	5.6	23.6	3.4	44.9	22.5
	Latvia	2.3	18.2	2.3	52.3	25.0
	Lithuania	14.9	24.3	2.7	44.6	13.5
Female	Estonia	5.7	13.6	4.5	52.3	23.9
	Latvia	0.0	20.2	0.0	47.2	32.6
	Lithuania	11.6	16.3	2.3	43.0	26.7

Source: made by the authors, based on COBEREN research data (percentage of respondent answers).

Table 4

Conformity to national identity

Gender	Country	Far appart	Small overlap	Moderate overlap	Large overlap	Complete overlap
Male	Estonia	1.2	11.6	44.2	39.5	3.5
	Latvia	2.3	13.6	40.9	35.2	8.0
	Lithuania	8.2	11.0	45.2	21.9	13.7
Female	Estonia	1.2	8.5	57.3	26.8	6.1
	Latvia	1.1	11.5	41.4	35.6	10.3
	Lithuania	5.1	16.7	44.9	29.5	3.8

Source: made by the authors, based on COBEREN research data (percentage of respondent answers).

For Lithuania and Estonia, the group dispersions of Lithuanian and Estonia parameter is $p = 0.608 > \alpha = 0.05$, and the authors retained the null hypothesis that there is no significant difference between the groups - Estonia and Lithuania averages.

Latvian and Estonian group variance ratio $p = 0.632 > \alpha = 0.05$, so it was not rejecting the null hypothesis that there is no significant difference between the mean values of the graduation class. Latvian and Lithuanian graduation class mean values are not significantly different, as evidenced by the resulting index $p = 0.15 > \alpha = 0.05$. The results obtained suggest that in the Baltic countries, females pay attention to the locally made products similarly (Table 3).

This study confirms the results of a study by S. Dzene. Dzene wrote in her doctoral dissertation that Latvian consumers attach a greater importance to local products – compared with the average in Europe, 19% more of the population of Latvia prefer locally produced food (Dzene, 2014).

Conformity to national identity

The authors of COBEREN wanted to find out the principles of consumer choice by their association with a national identity. In the Baltic countries consumers believe that the principles of their consumption are only partially influenced by their national identity.

Males of the Baltic States and national identity

Test of analysis of variance results obtained p-value = 0.110 with a significance level $\alpha = 0.05$ suggests that the group dispersion is similar. The calculation results indicate that $p = 0.698 > \alpha = 0.05$, so the null hypothesis is retained and the entire group averages are the same. Minor different Estonian and Lithuanian male consumer preferences conform to national identity.

The study showed insignificantly different Estonian and Lithuanian male consumers' self-identification with a national identity. Lithuania and Estonia, the group dispersion parameter $p = 0.766 > \alpha = 0.05$, and the authors adopted the null hypothesis that there is no significant difference between the groups - Estonia and Lithuania averages. Latvian and Estonian group dispersion parameter $p = 1.00 > \alpha = 0.05$, so the alternative hypothesis that there is a significant difference between the mean values of the graduation class was not accepted. However, it should be noted that the Latvian and Lithuanian graduation class mean values are not significantly different - the resulting pointer $p = 0.749 > \alpha = 0.05$. These results lead to the conclusion that the Baltic males' conformity to national identity is similar.

Females of the Baltic States and national identity

One factor analysis of variance results obtained p-value = 0.206 with significance level $\alpha = 0.05$ suggests that the group averages are different.

The calculation results indicate that $p = 0.052 > \alpha = 0.05$, so the null hypothesis is retained, the entire group averages are the same. The authors have come to the conclusion that there does not exist any differences between the formation of self-identity by Estonian and Lithuanian female consumers.

For Lithuania and Estonia the group dispersion parameter $p = 0.415 > \alpha = 0.05$, and the authors retained the null hypothesis that there is no significant difference between the groups - Estonia and Lithuania averages. Latvian and Estonian group variance ratio $p = 0.540 > \alpha = 0.05$, so it was not rejecting the null hypothesis that there is no significant difference between the mean values of the graduation class.

Latvian and Lithuanian graduation class mean values are not significantly different, as evidenced by the resulting pointer $p = 0.520 > \alpha = 0.05$. The results obtained suggest that in the Baltic countries the women conform to the national identity similarly.

Conclusions

Baltic consumers prefer locally made products. It means that locally made products are and will be in high demand. Consumers will choose products of local brands. Latvian males and females more often

choose locally made products compared to other Baltic countries. It can be concluded that the Latvian market is open to locally made products and producers of local brands.

Customers of the Baltic States do not pay special attention to brand names and the preference for the most famous brand products is not significant. The consumers of these countries differ in their choice for famous brands. Latvian males choose famous brand products more than Estonian and Lithuanian men. However, there is a difference between the Estonian and Lithuanian male choice of famous brands. Lithuanian males more often choose famous brand products. Likewise, it is Lithuanian women who more often prefer famous brand products. Thus, it can be concluded that the Lithuanian food market is more responsive to the most famous brand product manufacturers.

Consumer attention to brands in each Baltic country is different, so it can be concluded that the product that is required in one state may not be required in another. Latvian males and females more often pay attention to brands compared to other Baltic countries. It can be concluded that the Latvian people have more trust in brand products. Locally made product manufacturers, considering Latvian consumers' attention to brands and choice of locally made products, can successfully create local brand products.

Consumer conformity to national identity suggests that the consumer of Baltic States will consume the products, which are associated with their national identity. Baltic food producers are able to create local brand products have been associated with a sense of national identity.

Results from this study are useful for the food industry in the Baltic States and the European Union.

The obtained findings may help to understand the principles based on which the consumers in the Baltic States choose the products.

References

1. Batte M.T., Hu W., Woods T.A., Stan E. (2010) "Do Local Production, Organic Certification, Nutritional Claims, and Product Branding Pay in Consumer Food Choices?" *2010 Annual Meeting, July 25 - 27* (2005). Available at: http://ideas.repec.org/p/ags/aaea10/61026.html, 27 January 2013.
2. Dzene S. (2014) Sustainable Food Consumption Prospects In Latvia. SUMMARY of the doctoral dissertation for the scientific degree Dr.oec. Available at: http://llufb.llu.lv/dissertation-summary/food_economics/SkaidriteDzene_promoc_darba_kopsavilkums_2014_LLU_ESAF.pdf, 13 March 2013.
3. Fritz M., Rickert U., Schiefer G. (2009) "System Dynamics and Innovation in Food Networks." *British Food Journal* 2. Available at: http://ageconsearch.umn.edu/bitstream/59199/2/Hingley-Sodano.pdf, 27 January 2013.
4. Jin Yanhong H., Zilberman D., Heiman A. (2008) "Choosing Brands: Fresh Produce versus Other Products." *American Journal of Agricultural Economics* 90(2): 463–75. Available at: http://ajae.oxfordjournals.org/cgi/doi/10.1111/j.1467-8276.2007.01062.x, 4 March 2014.
5. Konecnik M., William C., Gartner (2007) "Customer-Based Brand Equity for a Destination." *Annals of Tourism Research* 34 (2). Available at: http://linkinghub.elsevier.com/retrieve/pii/S0160738306001368, 28 December 2013.
6. Martinez S., Hand M., Da Par M., Pollack S., Ralston K., Smith T., Vogel S., Clark S., Lohr L., Low S., Newman C. (2010) "Local Food Systems Concepts, Impacts, and Issues." *Economic Research Report* 97 p.
7. Oliveira-Castro J.M. (2008) "Individual Differences in Price Responsiveness within and across Food Brands." *The Service Industries Journal* 28(6). Available at: http://www.tandfonline.com/doi/abs/10.1080/02642060801988605, 6 March 2014.
8. Özsomer A. (2012) "The Interplay Between Global and Local Brands: A Closer Look at Perceived Brand Globalness and Local Iconness." *Journal of International Marketing* 20(2). Available at: http://journals.ama.org/doi/abs/10.1509/jim.11.0105, 11 March 2014.
9. Paasovaara R. (2012) "Understanding Consumers' Brand-Induced Food Taste Perception: A Comparison of 'Brand Familiarity'– and 'Consumer Value–brand Symbolism (in) Congruity'–accounts." *Journal of Consumer Behsviour 11*, April 2011. Available at: http://onlinelibrary.wiley.com/doi/10.1002/cb.356/full, 11 March 2014.
10. Parrott N., Wilson N., Murdoch J. (2002) "Spatializing Quality: Regional Protection and the Alternative Geography of Food." *European Urban and Regional Studies* 9 (3). Available at: http://eur.sagepub.com/cgi/doi/10.1177/096977640200900304, 7 March 2013.
11. Santos C.R., Ganassali S., Casarin F. (20130 *Consumption Culture in Europe: Insight into the Beverage Industry*. http://dialnet.unirioja.es/servlet/libro?codigo=542810, 3 January 2014.
12. Starr A. (2010) "Local Food: A Social Movement?" *Cultural Studiesâ†" Critical Methodologies* 10(6.) Available at: http://csc.sagepub.com/cgi/doi/10.1177/1532708610372769, 13 March 2013.

13. Stokburger-Sauer N., Ratneshwar S., Sen S. (2012) "Drivers of Consumer–brand Identification." *International Journal of Research in Marketing* 29(4). Available at: http://linkinghub.elsevier.com/retrieve/pii/S0167811612000572, 26 December 2013.
14. Veloutsou C., Moutinho L. (2009) "Brand Relationships through Brand Reputation and Brand Tribalism." *Journal of Business Research* 62(3). Available at: http://linkinghub.elsevier.com/retrieve/pii/S0148296308001483, 14 December 2013.

INFLUENCE OF PRODUCT ATTRIBUTES ON MILK CONSUMER'S CHOICE IN LITHUANIA

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Abstract
Consumer decision making is one of the most relevant topics in marketing. Therefore, organizations endeavour to create products in a way that correspond to their customers' needs and preferences. The emerging worldwide interest in healthy lifestyle and organic products could become the key success factor for food producing organizations. The article aims to determine the product attributes affecting consumer's choice of a milk product in Lithuania. The method of Conjoint analysis was chosen for the research. The research was provided as a repetition of the same research, done in 2009. According to the principles of the Conjoint analysis, six attributes of milk were named: 'Country of origin', 'Naturalness', 'Package size', 'Package type', 'Richness', and 'Price'. Each of the attributes was divided into several levels. While analyzing the structure of milk market in 2014, four market segments were distinguished: 'Irrationally price concerned', 'Rationally price concerned', 'Ethnocentric ecologists', and 'Richness concerned'. Such segments like 'Ethnocentric', 'Price-and-Richness concerned' or 'Ethnocentric price-concerned' have disappeared from the market during the five-year period. According to research results, following suggestions were made for the companies dealing with the milk market in Lithuania: first of all, a company has to make a decision about the segment to work with; afterwards, based on the results of conjoint analysis (conditional utilities of attributes levels), optimal propositions for every particular segment have to be composed.
Key words: conjoint analysis, consumer decision making, country-of-origin, milk, organic, price.

Introduction

Consumer decision making is one of the most relevant topics in marketing. The fulfilment of customers' wishes in a profitable way requires companies to understand which aspects of their product and service are most valued by the customer (Band and Shah, 2013). It is extremely important for organizations to understand the peculiarities of consumer preferences and their behaviour, concerning product choice. Considering product as a bundle of attributes, the assumption can be made that certain attributes affect consumer choice decision more than others.

Regarding the intensification of competition, the necessity for not only providing marketable agricultural and food products, but adapting economically effective farming methods is becoming vital for the organizations. On the other hand, growing consumer particularity and sophistication motivate the agricultural and food product manufacturers to practice the manufacturing and farming methods, which are environment-guarding and socially acceptable. The dimension of product's naturalness emerges. However, the producers of organic agricultural and food products often face grater expenditures, related to high standards for certifications of ecology. The final price (which is being paid by the end consumer) increases.

The other factor in the contemporary marketplace, which can be considered as one of the most important factors affecting consumer decisions while evaluating domestic as well as foreign products is product's country-of-origin. With the increased accessibility of foreign products the role of country-of-origin is even more significant. Many scholars (e.g., Henderson and Hoque, 2010; Sharma, 2011) have analyzed country-of-origin as a factor determining consumer's choice.

Therefore, an assumption can be made that such product attributes as naturalness, country-of-origin and price can be crucial while evaluating and choosing food, particularly, milk. Moreover, some more important product attributes, like product package or nutrition information can be named. However, the importance of every single attribute in purchase decision still lacks scientific substantiation. The problem of the research is expressed by a question: what product attributes affect consumer's decision while choosing milk and how can these attributes be managed.

The object of the research is product attributes affecting milk consumer's choice. The aim of the research is to determine the product attributes affecting consumer's choice of milk as a product. Following tasks were set achieving to reach the aim of the research:

- to determine the most important product attributes for Lithuanian consumers while choosing milk;
- to detect changes in the importance of milk's attributes for Lithuanian consumers during the five-year period;
- to segment the milk market in Lithuania;
- to provide suggestions for the companies dealing with the milk market in Lithuania.

Materials and Methods

Achieving to solve the research problem and to reach the aim, the method of full profile Conjoint

Table 1

Structure of milk attributes and attributes' levels

Attribute		Attribute's level					Total amount of levels
A1:	Naturalness	L11: Organic		L12: Conventional			2
A2:	Country of origin	L21: Lithuanian		L22:Imported			2
A3:	Package size	L31: 0.5 litre	L32: 1 litre	L33: 2 litre			3
A4:	Package type	L41: Plastic bag	L42: Tetra Pak	L43: Plastic bottle	L44: Glass bottle		4
A5:	Richness	L51: 1 %	L52: 2.5 %	L53: 3.5 %			3
A6:	Price	L61: 1.89 Lt	L62: 2.39 Lt	L63: 2.99 Lt	L64: 3.99 Lt	L65: 5.99 Lt	5
Total: 6 attributes		720 combinations					19 levels

analysis was chosen. The Conjoint analysis method is often used in practice in order to analyze the effect of certain product model preferences by consumer (Veith and Lianu, 2013). According to Band and Shah (2013), Conjoint analysis consists of generating and conducting specific experiments among customers with the purpose of modelling their purchasing decision. Milk (as a product) attributes and attribute levels were determined as a result of Focus group discussions in 2009 (for more information see Liesionis and Pilelienė, 2009). The determined attributes were listed as follows:

- **Country of origin.** For milk buyers in Lithuania one of the most important characteristics was decided to be the country of origin of the milk. In Lithuanian supermarkets and stores the milk produced in Poland, Latvia, Germany, etc. could be found. The main assumption here was that Lithuanians are ethnocentric people, while taking food consumption under consideration. Two attribute levels were named: 'Lithuanian' or 'Imported'.
- **Package size.** Three levels of package size were determined (with the regard to package sizes sold in most Lithuanian stores): '0.5 litre', '1 litre', or '2 litre'.
- **Package type.** Four possible attribute's levels were named, while discussing milk packages: 'Plastic bag', 'Tetra Pak', 'Plastic bottle', or 'Glass bottle'.
- **Richness.** With the regard to the richness of milk sold in Lithuanian stores, three levels of richness were identified: '1%', '2.5%', or '3.5%'.
- **Price.** The main assumption here was that people are willing to pay higher price for organic milk, in comparison to conventional. After the random inspection of prices in several Lithuanian supermarkets, five possible levels of milk price were established: '1.89 Lt', '2.39 Lt', '2.99 Lt', '3.99 Lt', or '5.99 Lt' (1 Litas = 0.2896 Euro).
- **Naturalness.** While talking about milk's naturalness, two attribute's levels were identified: 'Organic' or 'Conventional'.

The structure of milk attributes and attributes' levels is provided in the Table 1 below. As there can be seen in the Table 1, all possible combinations of attributes' levels (all possible product profiles) would result in 720 combinations.

Achieving to simplify the ranking procedure for respondents (the ranking method was chosen instead of rating because of its simplicity), the SPSS Orthogonal Design function was used to reduce the number of concept cards. Applying the SPSS 13 *for Windows* software package, the number of milk profiles was reduced to 25 possible product choices to place on concept cards, which had to be ranked by respondents by purchasing preferences.

The research was provided in January, 2009, and repeated in January 2014, in Kaunas, Lithuania. Respondents chosen were 25 – 45 years of age milk buyers: 18 women and 8 men in 2009, and 19 women and 8 men in 2014. According to Pullman et al. (2002), the majority of Conjoint analysis-based studies have been limited to 5 – 17 interviews. Product profiles (concept cards) were presented and explained for each respondent individually.

Results and Discussion

Conjoint analysis was provided by applying SPSS 13 for Windows software package. The relative importance of the chosen attributes and the utility scores of attributes' levels were calculated.

The research results provided in the Table 2 below showed that almost 27% of average customer's milk purchasing decisions depended on the product's country-of-origin back in 2009. However, the situation has changed during the five-year period. Consumer preference for Lithuanian milk has decreased in almost 8 percent; according to research results, country-of-origin is important, however, its position has dropped to the third place.

Table 2

Relative Importance of Milk Attributes and Attribute Levels' Utility Scores

Attribute	Attribute's importance (%)		Attribute's level	Level's utility score	
	2009	2014		2009	2014
A1: Naturalness	**10.11**	**22.38**	L11: Organic L12: Conventional	**0.8269** -0.8269	3.1821 -3.1821
A2: Country of origin	**26.84**	**18.90**	L21: Lithuanian L22: Imported	3.9455 -3.9455	2.7377 -2.7377
A3: Package size	13.15	8.99	L31: 0.5 litre L32: 1 litre L33: 2 litre	-0.8718 1.2051 -0.3333	-0.5210 0.7494 -0.2284
A4: Package type	11.14	9.45	L41: Plastic bag L42: Tetra Pak L43: Plastic bottle L44: Glass bottle	-0.0673 -0.3673 0.6942 -0.2596	0.3148 0.3963 -0.2630 -0.4481
A5: Richness	16.42	12.61	L51: 1% L52: 2.5% L53: 3.5%	-1.6462 1.6077 0.0385	-0.4210 1.0198 -0.5988
A6: Price	**22.35**	**27.68**	L61: 1.89 Lt L62: 2.39 Lt L63: 2.99 Lt L64: 3.99 Lt L65: 5.99 Lt	1.3692 1.9923 0.8385 0.0538 -4.2538	1.9926 2.2519 0.7185 -1.2815 -3.6815

The utility gap between selection of Lithuanian products and products provided by foreign producers remains high. The research results obtained in 2009 showed the difference of 7.891 conditional utility points. In 2014 the difference has decreased to 5.4754 conditional utility points. The latter result substantiates the previously obtained results (Šontaitė-Petkevičienė and Pilelienė, 2013), which indicate that in case of situation when faced with choice of similar products made in different countries, even 62.9 percent of respondents choose Lithuanian production. Lithuanian origin can be named as one of the most important and considerable attributes, while making purchase decision for milk. However, Lithuanian ethnocentrism has decreased (in comparison to 2009).

Research results reveal that milk price is the most important product attribute in 2014. Even 27.68 percent of purchase decisions are based on price (in comparison to 22.35 percent in 2009). Analyzing the conditional utility scores of price levels, it can be seen that the price of 3.99 Litas (which was considered positively in 2009) has been evaluated as having negative utility and considered being too high. However, despite the increase in the importance of price as a factor influencing purchase decision, the utility gap between highest and lowest attribute's levels has decreased from 6.2461 conditional utility points to 5.9334 conditional utility points, during the period. The latter change indicates better possibilities for reaching a counterbalance for high price using other product attributes.

A drastic change has been observed regarding the relative importance of milk naturalness. Naturalness was considered as the least important product attribute while choosing milk, back in 2009. However, during the five-year period the latter attribute has gained the second position – its importance has more than doubled from 10.11 to 22.39 percent. Moreover, the utility gap between organic and conventional milk became highest and resulted in 6.3642 conditional utility points (instead of 1.6538 back in 2009). Consequently, it can be suggested that negative consumer valuations of high price or foreign country-of-origin can be compensated by using naturalness as a factor.

The importance of milk richness has slightly decreased (in almost 4 percent) during the period. Moreover, a very rich milk (3.5 percent of fat) which was evaluated positively (0.0385 conditional utility points) in 2009, in 2014 was considered negatively (-0.5988 conditional utility points). Low-fat milk (1 percent of fat) still remains considered negatively; however, the negative attitude towards this attribute level is weakening.

Analyzing respondents' evaluations of the two remaining milk attributes: package size and package type, the decrease of their importance in purchase decision can be observed. Considering package size there should be noted that it is a highly price-related attribute. Moreover, 1 litre milk packages remain most wanted among consumers. While analyzing respondents' preferences regarding package type, it

Table 3

Final Cluster Centres

Variable	Clusters, 2014				Clusters, 2009			
	1	2	3	4	1	2	3	4
Country-of-origin	5.16	8.76	27.91	14.59	11.22	40.18	43.12	37.94
Naturalness	7.29	18.66	31.84	9.79	5.03	27.21	4.26	9.88
Price	62.32	19.04	16.10	10.81	30.03	9.78	26.04	13.56
Richness	10.95	8.18	9.99	44.75	24.02	5.36	5.09	18.29
Package size	7.43	28.32	6.38	5.03	17.09	9.53	14.64	6.10
Package type	8.15	17.03	7.79	15.03	12.61	7.94	6.87	14.22

can be noted that differences among various package types exist; however, the utility gap is very small in comparison to other product attributes and their levels.

The utility of every product proposition can be obtained as a sum of a constant (which is equal for every proposition) and the utilities of every attribute's levels used. The constant utility of milk as a product was found to be 11.5877 conditional utility points. Accordingly, the most valuable proposition would be: Lithuanian organic milk, containing 2.5 percent of fat, provided in 1 litre Tetra Pak, the price of which would be 2.39 Litas. The utility of such proposition (U) would result in:

$$U = 11.5877 + 3.1821 + 2.7377 + 0.7494 + 0.3963 + 1.0198 + 2.2519 = 21.9249 \quad (1).$$

As it can be seen, if the product proposition to a market is composed of the highest evaluated milk attributes' levels, the utility of such proposition to the consumer almost doubles. However, the highest utility for consumers not always results in a best way for an organization.

Achieving to simplify further analysis, cluster analysis was provided. Cluster analysis gave a particular guidance for segmenting the Lithuanian milk market (see Table 3).

As there can be seen in Table 3, the milk market structure has drastically changed during the five-year period. Four main clusters were determined in 2009; moreover, the first cluster was divided into the sub-clusters. Six main consumer segments were named; accordingly, Cluster 1 (the biggest one): (1) 'Price-and-Richness concerned'; (2) 'Price concerned'; (3) 'Richness concerned'; Cluster 2: (4) 'Ethnocentric ecologists'; Cluster 3: (5) 'Ethnocentric price-concerned'; and Cluster 4: (6) 'Ethnocentric'. All the respondents, who were making their choice decisions based on milk's naturalness, were concerned about product's country-of-origin. Only one cluster's (Cluster 1) purchase decisions were not based on the evaluation of country-of-origin.

While analyzing the structure of milk market in 2014, only one consumer segment related to country-of-origin can be found – 'Ethnocentric ecologists' (Cluster 3). As there can be seen in Table 3, the segments of 'Ethnocentric' and 'Ethnocentric price-concerned' have disappeared from the market during the five-year period. Moreover, segments of 'Price concerned' (Clusters 1 and 2) and 'Richness concerned' (Cluster 4) have clearly emerged. Cluster analysis highlighted that price concerned consumers can be divided into 'Irrationally price concerned' (Cluster 1) and 'Rationally price concerned' (Cluster 2). The difference between later clusters was found in consideration of package size while making purchase decision.

More detailed cluster analysis of 2014 data was provided by managing to identify the differences among final clusters. Therefore, differences between final cluster centres were calculated (see Table 4).

Table 4

Distances between Final Cluster Centres (2014)

Cluster	1	2	3	4
1		50.372	57.085	62.803
2	50.372		33.449	45.430
3	57.085	33.449		44.205
4	62.803	45.430	44.205	

While analyzing distances between final cluster centres, the lowest distance was found between clusters 2 and 3. Higher distances between clusters indicate greater dissimilarities. The biggest difference emerged between clusters 1 and 4, and clusters 1 and 3. It can be stated that 'Irrationally price concerned' consumer purchase decision is mainly based on product price; moreover, other product attributes' importance in decision-making process is very weak. In comparison, consumers belonging to all other clusters evaluate more than one product attribute during their purchase decision; moreover, the significance of price is low for clusters 3 and 4. Therefore, it can be stated that different combinations of a product have to be offered to different consumer segments.

Moreover, while analyzing consumer dissemination among clusters, the hugest cluster was

found to be Cluster 3 (55.6 percent of all respondents); Cluster 1 (Irrationally price concerned) took 26 percent of respondents; Cluster 2 (Rationally price concerned) – 11 percent of respondents; and Cluster 4 (Richness concerned) – 7.4 percent. Therefore, it can be stated, that even 37 percent of the market are taking price-based decision, while purchasing milk.

According to research results, the following suggestions can be made for the companies dealing with the milk market in Lithuania. First of all, a company has to make a decision about the segment to work with. Afterwards, based on the results of conjoint analysis (conditional utilities of attributes' levels), optimal propositions for every particular segment can be composed.

Price concerned. The core product's attribute determining choice decision of this segment is price. Accordingly, all other attributes have to be chosen achieving to minimize organizations costs, e.g., plastic bag, non-organic (conventional) milk, 1 % of fat richness. Despite possible division of latter segment into rational and irrational, organization hast to make package's size-related decision based on costs, as well.

Ethnocentric ecologists. This segment can be concerned as the 'Golden' segment for an organization. Ethnocentric ecologists can pay the highest reasonable price for an organic product (utility gap between organic and conventional milk results in 11.8396 conditional utility points); moreover, this segment prefers the Lithuanian origin of the product (utility gap between Lithuanian and imported milk results in 5.4754 conditional utility points). Considering the utility gaps between highest and lowest evaluated prices (5.9334) and package sizes (1.2704), even the price of 5.99 Lt for 0.5 litre package of Lithuanian organic milk (4.6358 conditional utility points) would result in better utility than 2.39 Lt for 1 litre imported conventional milk (-9.6358).

Richness concerned. The choice of the latter segment is mostly determined based on product richness. Therefore, the preferred richness can be attached to a higher product price or compensated by package-related attributes. The segment is the smallest in the market, hence, other marketing activities (e.g., advertising or publicity can be adapted to promote its growth). Moreover, research results highlight that consumers who care about milk's richness, do not care about the naturalness of a product. Therefore, conventional milk providing companies can consider this segment as their market opportunity.

Conclusions

Research results revealed that three attributes are most important for Lithuanian consumers while choosing milk, respectively: price, naturalness, and country-of-origin. Moreover, during the five-year period a drastic change has been observed regarding the relative importance of milk naturalness. Naturalness was considered as the least important product attribute while choosing milk, back in 2009; however, in 2014 the latter attribute has gained the second position. It can be stated that Lithuanian consumers are becoming more health-concerned and try to choose healthier food.

During the five-year period, the milk market structure in Lithuania has changed. While analyzing the structure of milk market in 2014, one consumer segment related to country-of-origin was determined and named 'Ethnocentric ecologists'. The segments of 'Ethnocentric' and 'Ethnocentric price-concerned' (which were found in 2009) have disappeared from the market during the five-year period. Moreover, segments of 'Price concerned' and 'Richness concerned' have clearly emerged. Cluster analysis highlighted that price concerned consumers can be divided into 'Irrationally price concerned' and 'Rationally price concerned'. The difference between later clusters was found in consideration of package's size while making purchase decision.

According to research results, the following suggestions were made for the companies dealing with the milk market in Lithuania: first of all, a company has to make a decision about the segment to work with; then, based on the results of conjoint analysis (conditional utilities of attributes' levels), optimal propositions for every particular segment have to be composed.

References

1. Band G., Shah N.V. (2013) Customer is the King... A Microscopic View into Selection of Tea Brand in Nagpur & Wardha. *Annamalai International Journal Of Business Studies & Research*, 5(1), pp. 56 – 67.
2. Henderson S., Hoque S.F. (2010) The Ethnicity Impact on Attitudes toward Country of Origin for Products with Different Involvement Levels. *Journal of International Consumer Marketing*, 22, pp. 271 – 291.
3. Liesionis V., Pilelienė L. (2009) Influence of the Ecological Factors on Consumers' Choice. *Management Of Organizations: Systematic Research*, 52, pp. 49 – 61.
4. Pullman M.E., Moore W.L., Wardell D.G. (2002) A Comparison of quality function deployment and conjoint analysis in new product design. *Journal of Product Innovation Management*, 19(5), pp. 354 – 364.

5. Sharma P. (2011) Demystifying Cultural Differences in Country-of-Origin Effects: Exploring the Moderating Roles of Product Type, Consumption Context, and Involvement. *Journal of International Consumer Marketing*, 23, pp. 344 – 364.
6. Šontaitė-Petkevičienė M., Pilelienė L. (2013) The impact of country-of-origin on food products choice. In: Changes in social and business environment: *proceedings of the 5th international conference*, Kaunas university of technology Panevėžys institute, Lithuania: selected papers, Kaunas: Technologija, pp. 189 – 196.
7. Veith C., Lianu C. (2013) Origin of the product and the buying decision. *Theoretical & Applied Economics*, 20(11), pp. 147 – 164.

THE PHENOMENON OF NON-GOVERNMENTAL ORGANIZATIONS: NEW STIMULI FOR CULTURAL DEVELOPMENT IN RURAL AREAS OF POLAND

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Abstract
The paper aims at analyzing the development of non-governmental organizations (NGOs) active in the field of culture, arts and the protection of cultural and national heritage, and their importance in shaping the cultural functions of rural areas of Poland in the context of their multifunctional development. The research has been conducted in the Kujawsko-Pomorskie voivodship. The data have been obtained from the foundations and associations database published by the Stowarzyszenie Klon/Jawor (the Klon/Jawor Association), from the statistical data published by the Central Statistical Office in Poland, and from the webpages of the analyzed organizations. The information on the NGOs as well as on the cultural institutions located in the rural areas of the Kujawsko-Pomorskie voivodship has been compared. It turns out that the development of the NGOs in rural areas of the Kujawsko-Pomorskie voivodship tends to have constant growth dynamics and that the presence of these organizations significantly increases the accessibility of cultural sector to residents and contributes to economic diversification. NGOs supporting the cultural sector have been developing only since 2000. Therefore, it can be assumed that the existing NGOs network is in its initial stage, but we may expect it will continue to develop. The NGOs are located mainly in urbanized and environmentally valuable areas. Considering the decreasing number of libraries and the types of initiatives undertaken by NGOs in the rural areas of the Kujawsko-Pomorskie voivodship we should state that the emerging NGOs can remedy current deficiencies and provide rural residents with access to culture.
Key words: non-governmental organization; culture; multifunctional development; rural areas; Poland.

Introduction

In the development strategies of both individual cities and entire regions, the cultural sector is identified as a crucial element determining their sustainable socio-economic development. In the 1980s in most countries of Western Europe and North America the cultural sector was perceived as a remedy for the problems of post-industrial cities (Bianchini, 1993; Kong, 2000a, 2000b; Stryjakiewicz, 2010). The research focused on the importance of the cultural sector for economic development resulted in the publication of many papers discussing both theoretical and practical aspects of cultural industries at the international, national, regional, and local level (e.g. Bianchini, 1993; Scott, 1997, 2000, 2004; Kong, 2000a, 2000b; Power, 2002; Power and Scott, 2004; Throsby, 2010; Środa-Murawska, 2013). While the researchers' attention has been focused mainly on large cities which have always been the centers of cultural life not only for their regions, we have to remember the crucial, although different role of the cultural sector in the development of towns and rural areas. The role may be considered in terms of, among others, protection of cultural heritage, development of tourism, and social capital.

Supporting the development of the cultural sector in rural areas becomes particularly important in the case of Poland, a country which has been in transition since 1989. The dismantling of State Agricultural Farms, the growth of unemployment, and the lack of new jobs have created the need to seek opportunities for the development of the Polish countryside in new conditions. The search for ways to change the perception of rural areas as monofunctional (with agriculture as the basis of economic activity) to multifunctional (with diversified rural economy) has been the subject of studies by many researchers in Poland (e.g. Falkowski, 1996; Szymańska and Matczak, 2000; Heffner, 2001; Fijałkowska and Jasiulewicz, 2003; Kłodziński, 2004, 2008; Czarnecki, 2005, 2009; Feltynowski, 2009) and in the world (e.g. Knickel and Renting, 2000; Huylenbroeck and Durand, 2003; Holmes, 2006; Râmniceanu and Ackrill, 2007; Wilson, 2007). In the papers concerning the multifunctional development of rural areas, the maintenance and protection of cultural heritage and the development of tourism are often pointed out as having the potential to diversify economic activity (Kłodziński, 2004).

Considering the importance of the cultural sector in the context of multifunctional rural development we should emphasize that in recent years in Poland, next to the main actors of cultural dissemination in rural areas, i.e. state and local cultural institutions, non-governmental organizations (NGOs) have been getting more and more active in the sphere of culture. Poland is a state with a very long tradition of charitable institutions, but after World War II the dominant player in the creation of social policy was the state. The situation changed after the new Act of 7 April 1989 (published in Dz.U. 1989 No. 20) had been introduced. The Act sanctioned the right

of people to form associations and made it possible to reconstruct the NGOs structures. That is why the development of NGOs has been observed in Poland only since 1990.

The problem is particularly important because rural areas in Poland comprise slightly more than 93% of the country's total area and are inhabited by almost 40% of the total Polish population. Moreover, in the analyzed voivodship (an administrative region of the 1st order in Poland) rural areas constitute as much as 95.4% of its total area (17,143 sq. km) and are inhabited by almost 40% (834,414) of its total population number. The rural areas of the Kujawsko-Pomorskie voivodship include 92 rural and 35 rural-urban (excluding urban parts) gminas (administrative regions of the 3rd order) (state as of 2013).

The following paper aims at analyzing the development of NGOs which are active in the field of culture, arts and the protection of cultural and national heritage and their importance in shaping the cultural functions of rural areas in the context of their multifunctional development on the example of the Kujawsko-Pomorskie voivodship. As such, the paper reflects a research trend describing changes in cultural services in Poland.

Materials and Methods

The necessary input data have been obtained from the foundations and associations database published by the Stowarzyszenie Klon/Jawor (the Klon/Jawor Association), from the statistical data published by the Central Statistical Office (CSO) in Poland, and from the data derived from the webpages of the analyzed organizations. The data on NGOs has been obtained from the foundations and associations database published by the Stowarzyszenie Klon/Jawor. It is the largest public database which contains information about all Polish foundations and associations, local government units and public institutions run by foundations, associations and local governments (http://bazy.ngo.pl). Information about all NGOs active in the field of culture, arts and the protection of cultural and national heritage and registered in rural settlements (we have considered only rural gminas and rural parts of urban-rural gminas) of the Kujawsko-Pomorskie voivodship has been separated from the database. Detailed information on the types of initiatives undertaken by individual NGOs has been obtained on the basis of their webpages content. In total, data for 117 NGOs which are active in the field of culture, arts and the protection of cultural and national heritage and are located within 64 gminas of the Kujawsko-Pomorskie voivodship has been collected. It is worth noting that some of the NGOs (e.g. foundations supporting local development, associations for the disabled and for the poor) do not conduct activities directly related to culture and arts; however, since their actions partially include broadly understood cultural education, they also contribute to some extent to the development of culture. In the study it is assumed that any NGO, which is active in the field of culture, arts and the protection of cultural and national heritage in rural areas enhances the development of the cultural sector and affects the availability of cultural services, and through its activity contributes to increasing the life quality of rural residents and the socio-economic development of a locality.

The data on population number, and the number of cultural institutions (libraries, cultural establishments, museums) for Poland and for all 144 gminas of the Kujawsko-Pomorskie voivodship have been derived from the database published by the Central Statistical Office at www.stat.gov.pl.

It should be emphasized that while the activities of government and local government cultural institutions in Poland have been constantly analyzed and monitored (e.g. reports of the Central Statistical Office: CSO, 2010, 2011, 2012, 2013), there have been only few studies of the NGOs active in the cultural sector. The most valuable reports and publications considering the role of NGOs in shaping culture in Poland have been created by the Stowarzyszenie Klon/Jawor and by the initiative called Obserwatorium Żywej Kultury (Living Culture Observatory), established relatively recently by the Narodowe Centrum Kultury (National Center for Culture) and the University of Warsaw in 2010.

The development of NGOs active in the field of culture, arts and the protection of cultural and national heritage in rural areas has been described on the basis of the year in which individual organizations were established. The importance of NGOs for the cultural development of rural areas has been, in turn, determined by using the criterion of quantitative equipment in cultural institutions per 1,000 inhabitants. The indicator defined in this way denominates the accessibility of services for residents. In the geographical and economic approach the notion 'accessibility' 'refers usually to the concept of proximity, ease of spatial interactions or potential contacts with functions' (Taylor, 1999). Accessibility may be considered in spatial, economic, and social aspects. Because of the purpose of the study we used social accessibility and expressed it with the index of services accessibility (Jakubowicz, 1993).

The paper aims at analyzing the development of NGOs active in the field of culture, arts and the protection of cultural and national heritage and their role in shaping the cultural functions of rural areas of Poland on the example of the Kujawsko-Pomorskie voivodship.

According to the aim of the study, the basic research problems have been set as:

- the structure of the cultural services sector in rural areas and the NGOs which are active in the field of culture, arts and the protection of cultural and national heritage;
- spatial layout of NGOs supporting the development of cultural services in rural areas of the voivodship;
- factors determining the spatial distribution of the NGOs active in the field of culture, arts and the protection of cultural and national heritage;
- an attempt to assess the impact of such NGOs on the general development of the cultural sector in rural areas.

The cognitive aim of the study comprises researching and describing the spatial differentiation in the formation of NGOs (which are active in the field of culture, arts and the protection of cultural and national heritage) structures and activities.

The research is mainly quantitative and partly qualitative. Determining a measurable participation of NGOs in the cultural development of rural areas is an extremely difficult task; however, the following research indirectly indicates the importance of the NGOs sector in the cultural development of rural areas and enables us to better understand the accessibility of cultural services in rural areas.

Results and Discussion

The restructurization of Polish economy which began in 1990 included also the sphere of culture. The results of the changes have been as follows: decrease in the number of libraries and their branches, closure of cultural establishments and of small cinemas replaced by multiplexes. The changes have caused a reduction in the accessibility of some cultural objects in relation to the number of residents, e.g. in small towns of Poland (Środa-Murawska, 2013).

Similar trends were observed in the Kujawsko-Pomorskie voivodship in the years 1995 – 2012 when a drop in the number of libraries per 10,000 population was noticed (compare Fig. 1).

In the analyzed voivodship the number of libraries declined more than 15% (from 515 in 1995 to 438 in 2012) but in rural areas more than 20% (from 341 in 1995 to 274 in 2012).

Interestingly, an increase in the accessibility of cultural establishments (basic cultural centers for local communities in Poland) was observed in the Kujawsko-Pomorskie voivodship in the years 2003 – 2012, but only in rural areas (see Fig. 2).

The number of cultural establishments in the Kujawsko-Pomorskie voivodship increased by 12% (from 183 in 2003 to 206 in 2012) and by 50% in the rural areas of the voivodship (from 91 in 2003 to 137 in 2012).

Thus, we can observe a decrease in the number of libraries and an increase in the number of cultural establishments in the rural areas of the Kujawsko-Pomorskie voivodship. Both types of institutions are responsible for the cultural development of local communities, especially in rural areas. Their activities have been strongly supported by various NGOs for

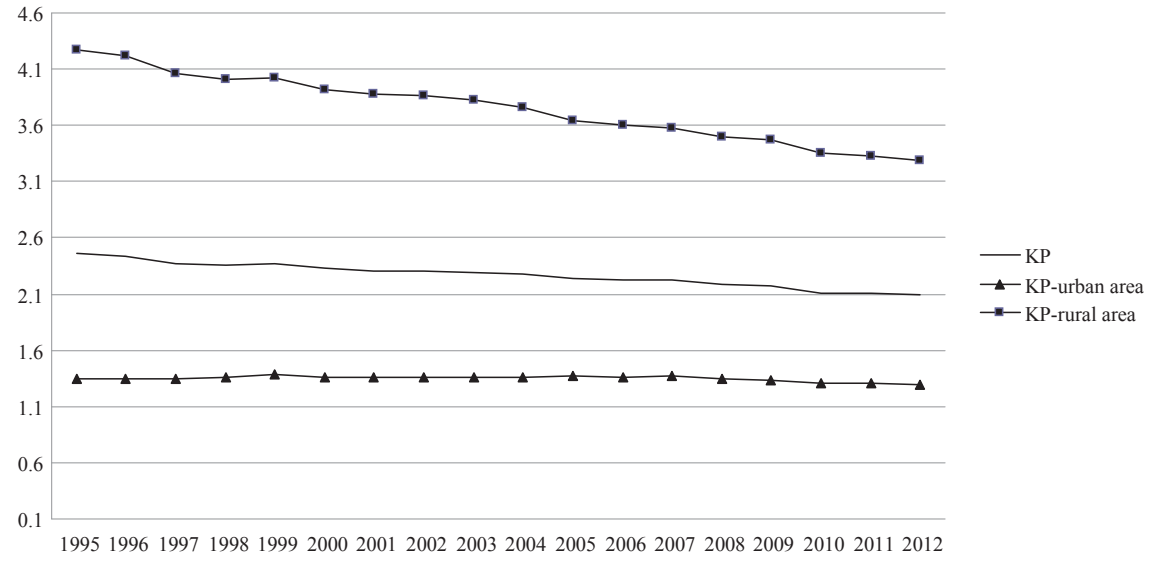

Figure 1. Accessibility of libraries (number of libraries per 10,000 population) in Kujawsko-Pomorskie voivodship in the years 1995 – 2012.

Explanation: KP – Kujawsko-Pomorskie voivodship.
Source: Own elaboration on the basis of www.stat.gov.pl.

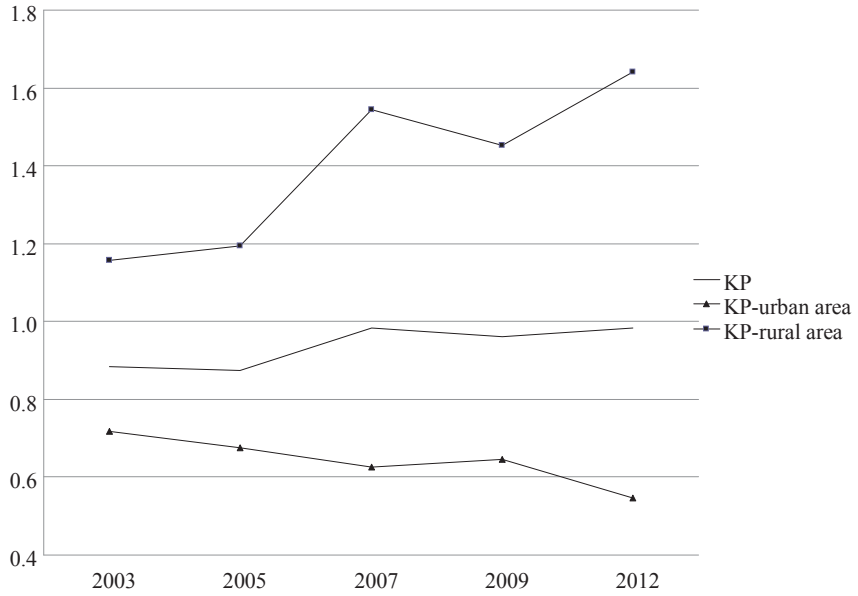

Figure 2. Accessibility of cultural establishments (number of cultural establishments per 10,000 population) in Kujawsko-Pomorskie voivodship in the years 1995 – 2012.

Explanation: KP – Kujawsko-Pomorskie voivodship.
Source: Own elaboration on the basis of www.stat.gov.pl.

several years. At the same time, in the rural areas of the voivodship the intensive development of NGOs which declare activities in the field of culture, arts and the protection of cultural and national heritage began only after 2000 (compare Fig. 3).

Although until 2000, the presence of NGOs active in the field of culture, arts and the protection of cultural and national heritage was noticed only in six rural gminas (i.e. 4.7% of all rural gminas and rural parts of urban-rural gminas), in the years 200-2004 and 2013 NGOs emerged in 29 and 64 (i.e. 50.4%) rural gminas and urban parts of urban-rural gminas respectively. The gminas in which NGOs are registered form several distinct clusters, e.g. there is a group of gminas neighboring the city of Toruń from the north and north-east; another group of gminas in the southern part of the voivodship surrounds the city of Inowrocław; there is also a group of gminas located in the northern part of the voivodship. A detailed analysis of individual gminas, localities and village administrator's offices in which the considered NGOs are situated reveals that many of them are environmentally valuable areas, e.g. the Wda Landscape Park, the Tuchola Forest, the Brodnica Landlake, the Chełmiński and Nadwiślański Landscape Park Complex, etc.

The high dynamics of the development of new NGOs (which are active in the field of culture, arts and the protection of cultural and national heritage) may indicate, inter alia, the increasing demand for this type of organizations, growth in the local communities' activity, and the development of alternatives to government institutions' forms of support for the cultural sector in rural areas.

The next step of the research has been to examine the accessibility of NGOs which are active in the field of culture, arts and the protection of cultural and national heritage in relation to 10,000 population in the Kujawsko-Pomorskie voivodship in 2013 (Fig. 4).

The average number of considered NGOs per 10,000 population in the rural areas of the Kujawsko-Pomorskie voivodship amounted to 2.8 in 2013; the lowest value of indicator totaled 0.75 and was observed in the rural part of the urban-rural gmina of Nakło nad Notecią, while the highest values were noticed in rural gminas: Raciążek (9.6), Zbiczno (8.4) and Sadki (8.1).

Besides the NGOs whose basic activity is the support of culture and development of the arts in the Kujawsko-Pomorskie voivodship, we have also considered groups of organizations for which cultural development is an additional activity. The groups include:

- organizations centered around the protection of national heritage and regional identity (e.g. Bractwo Czarnej Wody/the Brotherhood of Black Water) whose actions have contributed to cultural development (e.g. organization of regional songs concerts, exhibitions dedicated to the history of the region, publication of materials promoting the cultural heritage of the region and tourist guides, etc.);

- organizations supporting broadly understood socio-economic development of some locality,

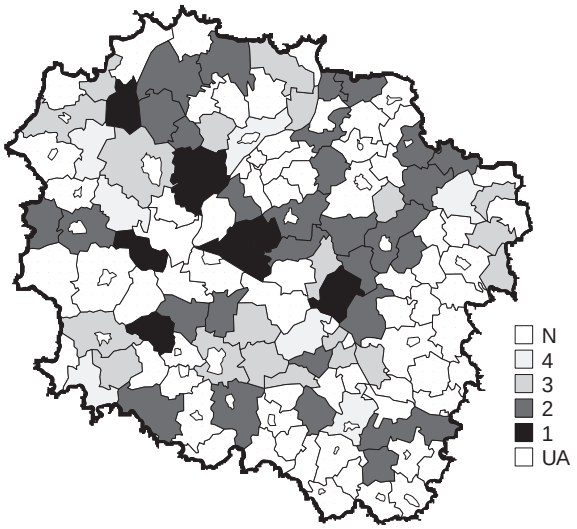

Figure 3. Year of establishment of the first NGOs active in the field of culture, arts and the protection of cultural and national heritage in the rural areas of the Kujawsko-Pomorskie voivodship.

Explanation: 1 – before 2000, 2- in the years 2000-2004, 3- in the years 2005-2009, 4 – after 2009, 5 – lack of NGOs active in the field of culture, arts, and protection of cultural and national heritage, UA – urban areas.

Source: Own elaboration on the basis of www.bazy.ngo.pl.

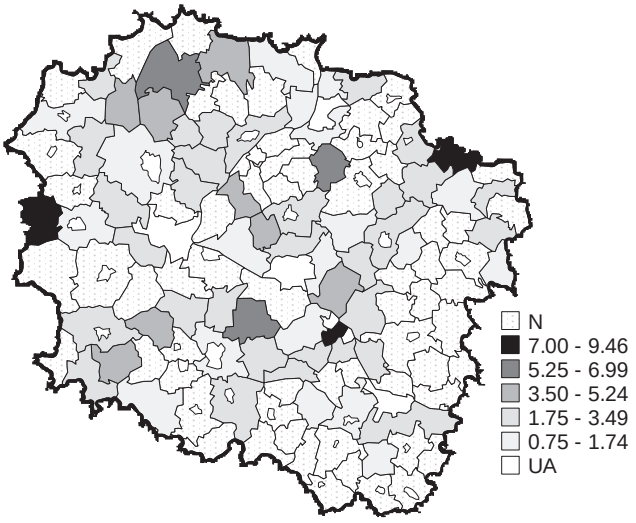

Figure 4. Accessibility of NGOs active in the field of culture, arts and the protection of cultural and national heritage per 10,000 population in rural areas of Kujawsko-Pomorskie voivodship in 2013.

Explanation: N – lack of NGOs which are active in the field of culture, arts and the protection of cultural and national heritage; UA –urban areas.

Source: Own elaboration on the basis of www.bazy.ngo.pl.

groups of localities or region (e.g. Stowarzyszenie na rzecz Rozwoju Gminy Bobrowo 'Aktywna Gmina'/ the Association for the Development of Bobrowo Gmina called 'Active Gmina', Stowarzyszenie na rzecz Rozwoju Wsi Mrozowa/the Association for the Development of Mrozowa Village, and Samostrzela 'Kłos') whose activities also include numerous initiatives promoting culture (e.g. creation of cultural heritage chambers; preparation of plays presenting the history of the region; preservation of traditions and cultural heritage protection);

- organizations attracting people with common interests and hobbies (e.g. Bractwo Rycerskie Ziem Toruńskich/the Brotherhood of Toruń Lands Knights; Fundacja na rzecz Tradycji Lotnictwa Polskiego/ the Foundation for the Polish Tradition Aviation) for

whom the cultivation of cultural traditions is uniquely important.

Among the 117 analyzed organizations 32% had their activities focused primarily on the development of the cultural sector. Next, there are 34 organizations supporting local development (29%), followed by brotherhoods and associations focused on the protection on national heritage.

Conclusions

In order to sum up the research results it should be emphasized that NGOs supporting the cultural sector have been developing only since 2000. Therefore, it can be assumed that the existing NGOs network is in its initial stage, but we may expect it will continue to develop (cf. Biegańska et al., 2014). NGOs active in the field of culture, arts and the protection of cultural and national heritage are located mainly in urbanized and environmentally valuable areas. Considering the decreasing number of libraries and the types of initiatives undertaken by NGOs in the rural areas of the Kujawsko-Pomorskie voivodship we should state that the emerging NGOs can remedy current deficiencies and provide rural residents with access to culture. The collected data indicate that NGOs active in the field of culture, arts and the protection of cultural and national heritage may and indeed do contribute to the economic diversification of rural areas. The huge diversity and multiplicity of NGOs activities makes it possible to verify the perception of rural areas only through the prism of agriculture and to change the perception of the cultural sector only through the prism of government and local government cultural institutions.

In the context of factors determining the spatial distribution of the NGOs active in the field of culture, arts and the protection of cultural and national heritage, we have shown that in rural areas the NGOs have been mainly located in environmentally valuable areas or near historic and cultural objects or the group of historic and cultural objects. Therefore the presence of objects of this type can be a stimulus for the development of NGOs active in the field of culture.

References

1. Bianchini F. (1993) Remaking European cities: the role of cultural policies. In: Bianchini F., Parkinson M. (eds.) *Cultural policy and urban regeneration. The West European experience*, Manchester University Press, Manchester, pp. 1 – 20.
2. Biegańska J., Środa-Murawska S., Grzelak-Kostulska E. (2014) Significance of EU funds in the creation of sport and recreation infrastructure in Poland in the context of the cohesion policy. In: Klímová V., Žítek, V. (eds.) *XVII. mezinárodní kolokvium o regionálních vědách. Sborník příspěvků*, Masarykova univerzita, Brno, pp. 409 – 416. ISBN 978-80-210-6840-7. DOI: 10.5817/CZ.MUNI.P210-6840-2014-51.
3. Central Statistical Office (Główny Urząd Statystyczny) (2010) *Działalność instytucji kultury w Polsce w 2009 r.* (The activities of cultural institutions in Poland in 2009). Urząd Statystyczny w Krakowie, Kraków, s. 7. (in Polish).
4. Central Statistical Office (Główny Urząd Statystyczny) (2011) *Działalność instytucji kultury w Polsce w 2010 r.* (The activities of cultural institutions in Poland in 2010). Urząd Statystyczny w Krakowie, Kraków, s. 12. (in Polish).
5. Central Statistical Office (Główny Urząd Statystyczny) (2012) *Działalność instytucji kultury w Polsce w 2011 r.* (The activities of cultural institutions in Poland in 2011). Urząd Statystyczny w Krakowie, Kraków, s. 12. (in Polish).
6. Central Statistical Office (Główny Urząd Statystyczny) (2013) *Działalność instytucji kultury w Polsce w 2012 r.* (The activities of cultural institutions in Poland in 2012). Urząd Statystyczny w Krakowie, Kraków, s. 14. (in Polish).
7. Central Statistical Office, Local Data Bank, Available at: http://www.stat.gov.pl, 01 January 2014.
8. Czarnecki A. (2005) Obszary wiejskie, urbanizacja wsi, rozwój wielofunkcyjny, rolnictwo wielofunkcyjne – przegląd pojęć (Rural areas, urbanization of coyntryside, multifunctional development, multifunctional agriculture). In: Rosner A. (ed.), *Uwarunkowania i kierunki przemian społeczno-gospodarczych na obszarach wiejskich*, IRWiR PAN, Warszawa, s. 233 – 254. (in Polish).
9. Czarnecki A. (2009) *Rola urbanizacji w wielofunkcyjnym rozwoju obszarów wiejskich* (Role of urbanization in multifunctional development of rural areas). IRWiR PAN, Warszawa, s. 232. (in Polish).
10. Database published by the Stowarzyszenie Klon/Jawor, Available at: http://www.bazy.ngo.pl/, 01 January 2014.
11. *Dziennik Ustaw* (2003) Nr 96, poz. 874 Przepisy wprowadzające ustawę o działalności pożytku publicznego i o wolontariacie (Database of Acts, 2003, No. 96, Item 874, Regulations implementing the Act on Public Benefit and Volunteer Work). s. 6467 – 6473. (in Polish).

12. *Dziennik Ustaw* (1989) Nr 20, poz. 104 Prawo o stowarzyszeniach (Database of Acts 1989, No. 20, Item 104, Regulations on Associations). s. 11. (in Polish).
13. Falkowski J. (1996) Społeczno-ekonomiczne i przestrzenne problemy wielofunkcyjnych obszarów wiejskich Polski (Socio-economic and spatial problems of multifunctional rural areas in Poland). In: Falkowski J., Rydz E. (eds), *Wielofunkcyjna gospodarka na obszarach wiejskich (ze szczególnym uwzględnieniem Pomorza Środkowego)*, Wyższa Szkoła Pedagogiczna, Słupsk, s. 45 – 54. (in Polish).
14. Feltynowski M. (2009) *Polityka przestrzenna obszarów wiejskich. W kierunku rozwoju wielofunkcyjnego* (Spatial policy of rural areas. Towards multifunctional development). CeDEWu, Warszawa, s. 224. (in Polish).
15. Fijałkowska E., Jasiulewicz M. (2003) Znaczenie upraw energetycznych w rozwoju wielofunkcyjnym obszarów wiejskich Pomorza Zachodniego (Importance of energy crops in the development of multifunctional rural areas of Western Pomerania). In: Górz B., Guzik Cz. (eds), *Współczesne przekształcenia i przyszłość polskiej wsi, Studia Obszarów Wiejskich*, T. 4, Bernardinum, Warszawa, s. 109 – 122. (in Polish).
16. Heffner K. (2001) Transformacja układów osadniczych wsi a wielofunkcyjny rozwój obszarów wiejskich (The transformation of rural settlement systems and multifunctional rural development). In: Bukraba-Rylska I., Rosner A. (eds), *Wieś i rolnictwo na przełomie wieków*, IRWiR PAN, Warszawa, s. 109 – 132. (in Polish).
17. Holmes J. (2006) Impulses towards a multifunctional transition in rural Australia: gaps in the research agenda. *Journal of Rural Studies*, 22, pp. 142 – 160.
18. Huylenbroeck van G., Durand D. (2003) *Multifunctional agriculture, a new paradigm for European agriculture and rural development*, Ashgate, Londyn, 239 p.
19. Jakubowicz E. (1993) *Podstawy metodologiczne geografii usług* (Methodological basis of services geography). Uniwersytet Wrocławski, Wrocław, s. 73. (in Polish).
20. Kłodziński M. (2004) Czynniki i bariery dywersyfikacji gospodarczej obszarów wiejskich (Factors and barriers of the economic diversification of rural areas). *Woda-środowisko-obszary wiejskie*, 4, 2b, s. 21 – 36. (in Polish).
21. Kłodziński M. (2008) Wielofunkcyjny rozwój obszarów wiejskich (Multifunctional rural development). In: Drygas M., Rosner A. (eds), *Polska wieś i rolnictwo w Unii Europejskiej. Dylematy i kierunki przemian*, IRWiR PAN, Warszawa, s. 15 – 24. (in Polish).
22. Knickel K., Renting H. (2000) Methodological and Conceptual Issues in the Study of Multifunctionality and Rural Development. *Sociologia Ruralis*, 40, pp. 512 – 528. DOI: 10.1111/1467-9523.00164.
23. Kong L. (2000a) Culture, economy, policy: trends and developments. *Geoforum*, 31(4), pp. 385 – 390.
24. Kong L. (2000b) Cultural policy in Singapore: negotiating economic and socio-cultural agendas. *Geoforum*, 31(4), pp. 409 – 424.
25. Power D. (2002) 'Cultural industries' in Sweden: An assessment of their place in the Swedish economy. *Economic Geography*, 78, pp. 103 – 127.
26. Power D., Scott A.J. (2004) *Cultural industries and the production of culture*, Routledge, London, p. 280.
27. Râmniceanu I., Ackrill R. (2007) EU rural development policy in the new member states: Promoting multifunctionality? *Journal of Rural Studies*, 23, 4, pp. 416 – 429. DOI: http://dx.doi.org/10.1016/j.jrurstud.2006.10.003.
28. Scott A.J. (1997) The cultural economy of cities. *International Journal of Urban and Regional Research*, 21(2), pp. 323 – 339.
29. Scott A.J. (2000) *The cultural economy of cities: Esseys on the geography of image producing industries*, Sage, London, p. 256.
30. Scott A.J. (2004) Cultural-products industries and urban economic development prospects for growth and market contestation in global context. *Urban Affairs Review*, 39, pp. 460 – 491.
31. Stryjakiewicz T. (2010) Krajobraz antropogeniczny, przestrzenie kreatywne a turystyka (Anthropogenic landscape, creative spaces and tourism). *Prace Komisji Krajobrazu Kulturowego*, 14, s. 52 – 62. (in Polish).
32. Szymańska D., Matczak A. (2000) Wielofunkcyjność - klucz do rozwoju wsi podmiejskich. Przykład gminy Wielka Nieszawka w strefie podmiejskiej Torunia (Multifunctionality - the key to rural development in suburban areas. Example of Wielka Nieszawka gmina in the suburban area of Toruń). In: Górz B. (ed.), *Szanse rozwoju rolnictwa i obszarów wiejskich ze szczególnym uwzględnieniem pogranicza polsko-ukraińskiego*, UMCS, KGR, GŻ PTG, Lublin, s. 187 – 197. (in Polish).
33. Środa-Murawska S. (2013) Usługi kulturalne w małych miastach (Cultural services in small towns). *Wiadomości Statystyczne*, 11/2013, s. 37 – 53. (in Polish).

34. Taylor Z. (1999) *Przestrzenna dostępność miejsc zatrudnienia, kształcenia i usług a codzienna ruchliwość ludności wiejskiej* (Spatial accessibility of employment, education and services and the daily mobility of the rural population). IGiPZ PAN, Prace Geograficzne, Wrocław, Nr 171, s. 239. (in Polish).
35. Throsby D. (2010) *Ekonomia i kultura* (Economics and culture), Narodowe Centrum Kultury, Warszawa, s. 182. (in Polish).
36. Wilson G.A. (2007) *Multifunctional Agriculture: a transition theory perspective*, CABI, Wallingford, Oxon, UK, p. 374.

INSTITUTIONAL DEPENDENCY MODEL FOR LITHUANIAN LOCAL GOVERNMENT IN THE CONTEXT OF HARMONIOUS MANAGEMENT

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Abstract
Self-government as representing the interests of the local population, social and political life organizing structure, occupies an important place in the political system of most of the countries. It is perceived as the lowest level of territorial division but as the closest one to civil society. Local self-government, in order to adapt to the changes, should focus on the investigation of the specific community issues, opportunities and needs of the development of the area. Currently, more and more relevant for district development stakeholders are becoming local authorities. The relevance of the topic is signified by the fact that the ever-changing environment provides people with new opportunities, but also causes a lot of problems. European district development policy provides new features for countryside areas, such as economic, social, environmental and territorial ones. The changes radically change the concept of local development and activities: from a centralized model of transition to exogenous and endogenous decentralized model, the latter based on local initiatives and resources, and innovations. The research objective is to single out theoretical possibilities for the application of the institutional dependency model in order to ensure the harmonious governance of Lithuanian local authorities. An assumption is made that this is a new opportunity for improving the governance process of territorial self-government. The research is based on the scientific literature, document analysis and synthesis, systematization, case studies, comparative analysis and visualization methods.
Key words: Local government, Institutional dependency model, harmonious management.

Introduction

Currently Lithuanian local authorities are becoming increasingly significant participants in public governance. Self-government - as a structure which represents interests of local residents and organizes public and political life - plays an important role in the political system of most states. It is perceived as the lowest level of territorial division but as the closest one to civil society. Autonomy allows citizens to express their interests, to control their fulfilment and to influence other state authorities. A constantly changing environment provides new opportunities to people and at the same time creates a number of problems. These changes transform the concept of area development and the execution of activities: one can notice transition from the centralized exogenous model to the decentralized and endogenous or even neo-endogenous model. The latter model is based on incentives, resources and innovations created by individuals. The development of Lithuania is inseparable from the long-term strategic trends and priorities of the European Union development. In this context the aspect of coherency gains importance when various areas of activities require the implementation of the functions of not only economic but also social, environmental protection and territorial development. This article emphasizes the harmonious governance of the public sector, which manifests itself through the adjustment of separate functions of local authorities as well as their independence.

The research object is the harmonious governance of local authorities.

The research objective is to single out theoretical possibilities for the application of the institutional dependency model in order to ensure the harmonious governance of Lithuanian local authorities.

To achieve the objective, the following ***tasks*** were formulated***:***

1. To identify types of activities of local authorities and to assess their inter-compatibility through the use of the institutional dependency model.
2. To indicate improvable areas of governance assigned to local authorities in order to ensure harmonious governance.

Materials and Methods

The article is of a cognitive and application nature. It proceeds in three steps. Firstly, were analyzed the concept of local self-government. Secondly, we presented the model of institutional dependency and it was integrated into the harmony management context. And finally, we suggested the opportunities to single out the following improvable areas of governance assigned to local authorities. The paper is based on the scientific literature and document (laws) analysis and synthesis, systematization, case studies, comparative analysis and visualization methods.

Results and Discussion

After the restoration of independence, the Republic of Lithuania was determined to become a democratic state governed by the rule of law. One of the renowned Lithuanian scholars P. Leonas (1991) claimed that ‘until recent years a genuine democratic form of organisation of state government was deemed the most appropriate for the creation of the most convenient forms of cultural life intended for the general public‘. It is impossible to implement democracy if citizens

fail to directly participate in the governance of the society and to reach decisions on political, economic safeguard, cultural and other issues which are relevant to the community of local self-government. Therefore, the presence of developed local self-government is one of the essential elements of a democratic state. In a general sense self-government is perceived as 'the ability of the system of government to maintain and improve parameters without any other significant external impacts through the use of its own strengths and possibilities'(Kūris, 1990). From the viewpoint of sociology and management, 'self-government manifests itself through the involvement of all members of a social organization in examining, reaching and implementing common decisions' (Mueller, 2004).

Modern science views self-government as 'the independent functioning of an organisation whose members ensure its operation through the adoption of decisions and norms related to the existence of the organization and the resolution of common problems' (Morphet, 2008). However, this was not always a widespread perception of self-government. 'European lawyers viewed self-government as a relatively independent form of government the prevalence of which was possible when citizens made their interests a primary consideration directly or through their elected representative authorities' (Urmonas, 2011). This definition allows the following two interpretations of self-government: (1) in a broad sense, any state can be regarded as a self-governing organization if its government is elected and relies on the will of the nation; 2) in a narrow sense, one can refer to communities which form and function inside the state. In this sense the concept of self-government is synonymous with the notion of local self-government, when local residents but not representatives of central government are concerned with economic or other issues of a certain administrative and territorial unit. The present Local Self-Government Act of the Republic of Lithuania (2008) defines local self-government as 'the self-regulation and self-action of the community of permanent residents (which is entitled to self-government under the Constitution) of the administrative unit of the state territory (which is established by law) in accordance with the competence prescribed by the Constitution and law'.

In general it can be stated that local self-government is a structure which represents interests of local residents and organizes public and political life, and plays a significant role in political systems of different states. It can be viewed as the lowest level of territorial division but as the closest one to civil society enabling citizens to express their interests, control their fulfilment and influence the functioning of the state.

According to A. Urmonas (2011), 'self-government, as an ideal social form of government which develops beyond time and space limits and does not depend on human factors, can be considered a utopia'. Hence it is necessary to analyse entities of local self-government. Entities of local self-government constitute a uniform multi-stage system which consists of the following elements indicated by A. Astrauskas (2004):

- 'the representative authority of a municipality, i.e. the council with the following two formations: the municipal supervisory authority and council committees and commissions;
- the executive authorities of a municipality (usually a single authority, but the presence of several authorities is also possible);
- the administration of a municipality'.

Each entity or a group of entities of local self-government plays a certain role in a specific part of the state territory and can be referred to as the entity of municipal authority, municipal political authority, municipal public authority or public administration, which acts on the basis of the principles of public administration specified in the Local Self-Government Act of the Republic of Lithuania (2008). In accordance with Article 3 of the Local Self-Government Act of the Republic of Lithuania (2008), a municipality is 'the administrative unit of the state territory having the status of a legal entity and the right to self-government (under the Constitution the Republic of Lithuania) which is implemented through the municipal council'. A municipality is the main authority which is responsible for the management of local affairs. The freedom of local municipal authorities is restricted due to their functions. Municipal authorities are not empowered to establish their powers, i.e. these bodies cannot establish their competence independently. State authorities determine the competence of municipal authorities. Pursuant to the competence and obligations to the community granted by the Constitution and law, municipalities can make decisions merely in relation to the execution of independent functions. Thus, taking interests of residents into consideration, municipalities perform functions which are transferred to them by the state. When implementing the latter functions, municipalities have restricted freedom, which is prescribed by law, to adopt resolutions and decisions of state authorities and/or state officials. In some cases state functions can be assigned to municipalities on the basis of concluded agreements. As a rule, the execution of these functions is temporary and season-dependent. Based on the nature of activities, municipal functions are divided into the following groups: functions of local government, functions of public administration and functions of public service provision.

An eldership is another important authority from the perspective of local self-government. The Local Self-Government Act of the Republic of Lithuania (2008) defines an eldership as 'the subdivision of municipal administration operating in a certain part of the municipal territory. The municipal council establishes their number, names, territorial boundaries and functions which are transferred by municipal administration'. From this perspective, an eldership can be viewed as the structural territorial subdivision of municipal administration (its subsidiary, speaking the language of business) which acts as an intermediary between the residents of the eldership and the municipality. According to J. Mačiulytė, M. Dedeire and R. Prapiestienė (2013), due to its territorial government Lithuania stands out from Central European and Baltic countries. The implementation of the administrative and territorial reform validated self-government not at the lowest level but at the intermediary sub-regional level. Soviet-era neighbourhoods were abolished and legitimately replaced with elderships which became municipal structural administrative subdivisions (Daugirdas and Mačiulytė, 2006). The absence of local authorities distanced the local government from citizens and prevents social and economic development in towns and rural areas.

I. Vidrevičienė (2010) points out that the main tasks of elderships involve: 'the strengthening of communal relationships, the encouragement of resident participation in the process of local self-government and the achievement of their social and economic welfare'. Therefore, it can be stated that the objective of elderships is to develop local self-government as the basis for the development of the democratic state within the limits of assigned territories and to implement transferred public administration functions.

Elders of sub-elderships, whose activities are validated by the Local Self-Government Act, should serve as a link between the local community, municipality and superior organizations of self-government. The Local Self-Government Act of the Republic of Lithuania (2008) provides that an elder of a sub-eldership is 'a representative who is elected by the community of the residential area which belongs to the territory with the office of the eldership'. Residents can elect elders of sub-elderships from the available representatives of the above-mentioned community to perform public work for a two year period. Candidates for this position can also be proposed by residents, nongovernmental organisations and associations as well as institutions and organisations operating within the limits of the sub-eldership. The following rights and duties reflect the main activities of elders of sub-elderships: '(1) to represent interests of sub-eldership residents in the eldership office, municipal authorities and state institutions operating in the municipal territory; (2) to encourage sub-eldership residents to handle matters concerning the territory of the residential area (to maintain roads, streets, squares, cemeteries and other infrastructure facilities); (3) to develop and organise the cultural and sport life of the village (town and city); (4) to receive information materials and projects of legal acts and to notify sub-eldership residents of decisions adopted by different organizations' (Vidrevičienė, 2010).

Having completed the analysis of local self-government, it can be claimed that local self-government serves as an important link between people and elements of public administration. Thus, in a broad sense local self-government can be regarded as a territory where the implementation of national policy rests on the execution of specific work. In addition, local authorities perform a number of assigned functions the implementation of which allows self-government entities to control the major areas of public life. Therefore, it can be concluded that the main objective of local authorities is to promote and develop local self-government as the basis for the development of the democratic state, i.e. to develop democracy within the country and to encourage residents to take initiative when dealing with relevant issues of communal life without anticipating directions from superior authorities. Hence, it can be asserted that the goal of local authorities is to contribute to national policy formation by engaging residents in the decision making-process and ensuring their social and economic welfare.

Based on the analysis of the elder's functions, it can be stated that an elder is in charge of not merely administrative governance of rural areas. According to M. Duobaitė (2010), 'an elder executes more significant and broader functions regarding the management of changes in rural areas, for instance, he/she promotes resident initiatives, motivates resident participation in the change management process and the like'. Being a community leader is one of the fundamental roles of an elder. Research carried out by the American Management Association stands as a proof of it. The study reveals that 'successful change management is determined by leadership, corporate values and communication. Leader's convictions have influence on his/her attitudes towards problem-solving techniques' (Korsakienė, 2006). Some authors believe that there is a connection between leadership and some type of instructions, i.e. personal power is used to win people over to work together towards a common goal. However, it is also emphasized that 'latter-day leaders face two major difficulties: they must ensure that people adjust to changes and foresee future perspectives' (Korsakienė, 2006). Therefore,

it can be claimed that the role of leaders in the governance process has a substantial effect on the successful development of the area.

It can be concluded that the development of areas depend on the capability of local authorities (in this case the ability of the municipality or eldership) to effectively work and collaborate with other authorities in stimulating resident activities. 'Both communities and other non-governmental organisations play a significant role in areas, especially when they prepare and implement projects related to the practical application of harmonious governance provisions:

- to raise public awareness, to consult and to provide information which stimulates life changes;
- to promote civil initiatives and public participation when resolving social, economic and environmental problems of the local community;
- to initiate the cooperation between non-governmental organisations and educational institutions' (Vietos savivalda.., 2010).

As it was mentioned before, the development of areas does not occur by itself: the process is always in control and under the influence of organizations, also known as local authorities, which are responsible for its functioning. According to the authors, in addition to direct government authorities, such as municipalities and elderships, the development of areas is also affected by the following bodies: public employment offices, business enterprises, local activity groups, rural community organizations, non-governmental organisations, police authority and other property protection services, cultural centres, libraries, educational/training/consulting institutions and other active residents or their groups. Thus, an assumption can be made that community organizations, which institutionally do not belong to authorities of public governance, are becoming increasingly important participants in the development of areas.

Governance is concerned with the relationship and relative importance of the formal and informal institutions shaping activities. The concept of institutions refers to the rules, norms and strategies that shape individual and organizational behavior (North, 1990; Ostrom, 1999). Institutions are persistent, predictable arrangements, laws, processes or serving to structure political, social and economic transactions and relationships in society. They may be formal, including legislation and parliamentary procedures, or informal, such as cultural rules for decision making (Handmer and Dovers, 2007; Pelling and Holloway, 2006). The goals of formal and informal institutions may be either compatible or conflicting (Pahl-Wostl, 2009), and if the two types of rules systems complement each other than governance processes are likely to be more efficient and effective – measured, for example, by lower rates of corruption.

The above framework substantiates the model of institutional dependency (Figure 1) (Borzel and Risse, 2000), which treats actors from the utility point of view, in the sense that they act for maximizing their preferences. Not excluding the possibility of a preference change, the model presupposes that the national actors have an essential interest in the organizational survival, autonomy and development, and their preferences are predominantly shaped by the institutions.

The interdisciplinary synthesis that model of institutional dependency presupposes ensures the specific difference from the institutionalism of the rational choice, emphasizing that institutions include not only norms, but also social norms, regulating the actors' conduct and ensuring the social

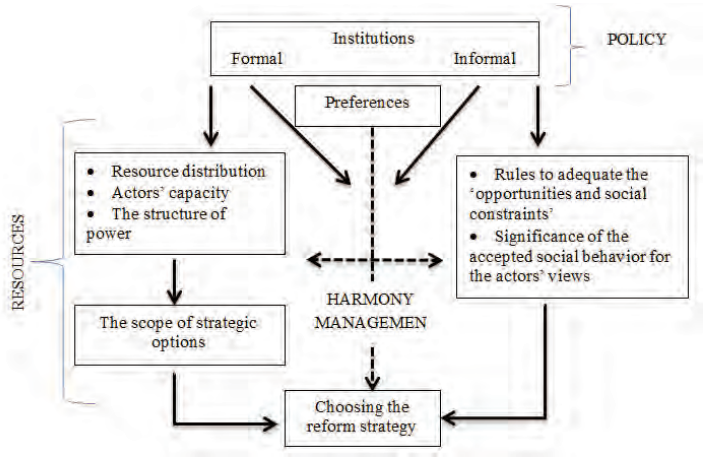

Figure 1. The model of institutional dependency in the context of harmony management.
Source: prepared authors by Borzel and Risse, 2000.

appropriateness of their actions. Model of institutional dependency systemically approaches more factors - on sociological, economic, political or juridical grounds - and one may conclude that choosing certain reform strategies is not only an issue regarding the available resources and the cost-benefit analysis of the expected utility, but also a function of the actors' strategic preferences and options.

It is important to combine choices and goals of local authority representatives and other actors who express interest in the prosperity of the area on the basis of the concept of harmonious governance. The theory of harmonious management is the application and development of harmonious theory to the management field, the main concern of which is how to achieve harmony in the all subsystem so that can get harmonious purpose as a whole (XI et al., 2001). The basis of the harmonious management will originate from three main hypotheses, such as 'person is ultimate source of uncertain factor in management action'; 'the uncertainty of material factor can be recognized and controlled ultimately within person cognition'. Based on the premises, it will abandon the fundamental framework of 'planning, organizing, leading and controlling' and divide out correspondingly "He" and "He rules", "Xie" and "Xie rules" according to the cognition of the harmonious theme (XI et al., 2005).

Therefore, the ultimate aim of harmonious management theory is to bring forward one kind of comparatively overall solution to a series of management problems with uncertainty in complicated and changeable environment. The theory can explain and foresee all management phenomena which have already happened, are happening and will happen, can make management practice become accurate, and can simplify and ease the operation (XI et al., 2004). One of the most important features of the self-government is an orientation toward the social initiatives (Owsiak, 2005). Participation in the process of decision taking dealing with allocation of resources gives the sense of responsibility and promotes actions fostering the socio-economic development. The ability to manage independently one's own matters, and related to it assignment of responsibilities for task realisation, leads to the state when having some autonomy is very important for the self-government that is expressed in independency and undergoes some judicial protection as a legal entity.

Management is most often defined as an effective administration, use and coordination of the resources, such as: capital, equipment, materials and work for reaching set aims. It results from the definition that management includes any activities concerning planning, organisation, leading and controlling that aims at coordination of the organisation resource use for efficient and effective realisation of its goals. Management includes three types of processes i.e. decision making, execution and control (Kożuch and Książek, 2013).

The most common form of public administration decentralisation is the local self-government that is seen as a relation of a local community, named in the structure of the state, established and governed by law, appointed to realise independently tasks of public administration, equipped in material resources allowing realisation of the tasks (Ochendowski, 2002). The core issue of the local self-government is to manage the public affairs by the concerned community itself (Tarno, 2004).

The independence of the self-government should be considered in a few aspects. The law aspect sees it as awarding self-government the legal entity, that is understood as independence and ability to manage its own matters. The political aspect is a result of allocation the right to choose the direction of actions. The economic aspect is related to realisation of tasks and performing the activity, with taking into account the real conditions under which those organisations function, that particularly include: rise of public sector importance, necessity to accept the changes in the technique, influence of the market economy and globalisation, the need to regulate the expenses on the public services and so on (Filipiak-Dylewska, 2002).

One of the most important tasks of the territory self-government is to guarantee appropriate conditions for local development. It constitutes a harmonised and a systematic activity (the changing complexity) of the community, public authorities and other operators functioning within a given unit of the territory self-government, aiming at creation of the new and improvement of the existing usability conditions of the territory unit, creation of favourable conditions for the economy and provision of the spatial and ecological order (Parysek, 1996).

As it was mentioned before, the development of areas is affected by the combination of endogenous and exogenous environmental factors, which creates conditions for the existence of a new neo-endogenous model of rural development. Neo-endogenous thinking is based on institutional development theories. The institutional dependency model reflects theories which rest on the idea that the ability of local authorities (actors) to mobilize internal resources, to cope with external power structures which impact the area and to create proper strategic insights forms the basis for the development of the area. This should be combined together with measures which allow one to achieve strategic goals by ensuring that the actors of the rural area participate in internal and external development processes and by creating acceptable meanings and rules of social behaviour. V. Atkočiūnienė and R. Vaišnoraitė (2012) point out that institutionalists tend

to direct a great deal of their focus on the explanation of economic and political motives of individuals' behaviour.

Based on the elements of the institutional dependency model it becomes possible to single out the following improvable areas of governance assigned to local authorities:

1) the strategic planning of local authorities;
2) the personnel of local authorities and the combination of capabilities of actors who belong to other significant organisations and show their own initiative;
3) the social capital of the area;
4) the ability of local actors to recognize the competitive advantages of the area and to use them in strategic planning.

Planning is the primary function of governance. It lays the foundations for other three functions of management which include organisation, governance and supervision. Only in the presence of a long-term plan it is possible to select executors, create structures, delegate functions, distribute assignments, motivate and manage executors, ensure communication between executors, assess their performance and the like. Therefore, it can be claimed that strategic planning is executed by municipalities.

Conclusions

1. Local self-government is one of the main elements of the state, which acts within a given territory. In a local government, the system cannot guarantee contemporary democratic state. The democratic society means a more developed local self-government.
2. The main aim of local authorities - to contribute to public policy development and implementation, to solve problems of local residents, to stimulate people's initiative in decision-making process. By type of activity of local self-government for local government, public administration and public service functions. In other words, local authorities play an intermediate role between citizens and government.
3. Local self-government has the right to define all functions and actions, which can freely and independently manage the municipality. The right to act freely and independently means for municipal authorities the right to take decisions according to the Constitution and the law. Local self-government institutions that have statutory competence and may dispose of financial resources can operate freely in many citizens' daily lives.
4. In seeking to improve the governance of local authorities and to ensure its harmony, it was established that if local authorities applied spatial strategic planning, it would create greater possibilities for the improvement of life conditions of the area residents through the proper use of available resources. If created and introduced, the effective integrated harmonious system of government would enable one to improve the governance of these authorities, to optimize the system of strategic planning, to enhance the transparency of supervision and governance, to use the possibilities of information technology at the maximum, to adopt contemporary management techniques and the European experience of public governance.
5. Based on the elements of the institutional dependency model, it becomes possible to single out the following improvable areas of governance assigned to local authorities: the strategic planning of local authorities, the personnel of local authorities and the combination of capabilities of actors who belong to other significant organisations and show their own initiative, the social capital of the area, and the ability of local actors to recognize the competitive advantage of the area and to use them in strategic planning.

References

1. Astrauskas A. (2011) Vietos savivaldos raida Lietuvoje 1990 – 2010 metais (Local self-government in Lithuania in 1990 – 2010). *Viešoji politika ir administravimas*, vol. 10 Issue 2, pp. 283 – 298. Available at:http://web.ebscohost.com/ehost/detail?vid=18&hid=112&sid=bc540c7611ac41fabae7df54d5c89ea7%40sessionmgr114&bdata=JnNpdGU9ZWhvc3QtbGl2ZQ%3d%3d#db=a9h&AN=64151521, 25 February 2014. (in Lithuanian).
2. Atkočiūnienė V., Vaišnoraitė R. (2012) Kaimiškųjų vietovių vystymo strateginio proveržio sąlygos: Dargužių kaimo atvejis (Rural development strategic breakthrough conditions: Dargužiai rural case). *Žemės ūkio mokslai.* T. 19. Nr. 3, pp. 180 – 191. (in Lithuanian).
3. Daugirdas V., Mačiulytė J. (2006) Decentralizacija ir teritorinė savivalda Lietuvoje (Decentralization and Local Government in Lithuania). *Politologija*. 3(43). pp. 91 – 110. (in Lithuanian).
4. Filipiak-Dylewska B. (2002) Procedury budowy strategii finansowania zadań własnych gminy (Procedures for construction financing strategy tasks of the municipality). Szczecin: Pub. Naukowe Uniwersytetu Szczecińskiego, s. 421. (in Polish).

5. Korsakienė R. (2006) Organizacinių pokyčių valdymas: teoriniai ir praktiniai aspektai (Organizational Changes Management: Theoretical and Practical Aspects). *Verslas: teorija ir praktika*, Nr. 4, pp. 237 – 242. (in Lithuanian).
6. Kożuch A., Książek E. (2013) Local government management – an attempt to define the term and its scope. Management Theory and Studies for Rural Business and Infrastructure Development. Vol. 35. No. 4. Scientific Journal, pp. 59 – 69.
7. Kūris E. (1990) *Savivalda, demokratija, teisė (Self-governance, democracy and the law)*. Vilnius, pp. 85. (in Lithuanian).
8. Leonas P. (1991) *Lietuvos savivaldybės (Lithuanian municipalities)*. Kaunas, pp. 38. (in Lithuanian).
9. Lietuvos Respublikos vietos savivaldos įstatymo pakeitimo įstatymas (The Local Self-Government Act of the Republic of Lithuania). (2008) Available at: http://www3.lrs.lt/pls/inter3/dokpaieska.showdoc_l?p_id=327811&p_query=&p_tr2, 19 February 2014. (in Lithuanian).
10. Mačiulytė J., Dedeire M., Prapiestienė R. (2013) Lietuvos kaimo bendruomenės ir lokalinis vystymas (Lithuanian rural community and local development). *Geografija*. T. 49(1), pp. 69 – 81. (in Lithuanian).
11. Morphet J. (2008) *Modern local government*. SAGE publications. Available at: http://books.google.lt/books?id=jLxDmZlrdWQC&pg=PA34&hl=lt&source=gbs_toc_r&cad=3#v=onepage&q&f, 15 January 2014.
12. Mueller K.J., Slifkin R.T., Shambaugh-Miller M.D., Randolph R.K. (2004) Definition of Rural in the Context of MMA Access Standards for Prescription Drug Plans September 27, RUPRI Center for Rural Health Policy Analysis, North Carolina Rural Health Research and Policy Analysis Center. Available at: http://www.rupn.org/ruralPolicy/publications/p2004-7.pdf, 15 January 2014.
13. North D.C. (1990) *Institutions, institutional change and economic performance*, Cambridge: Cambridge University Press, pp. 75.
14. Ochendowski E. (2009) Prawo administracyjne (Administrative Law). Część ogólna. – Toruń: TNOiK, s. 502. (in Polish).
15. Ostrom E. (1999) Institutional rational choice, in P. A. Sabatier (ed.) *Theories of the policy process*, Boulder CO: Westview Press, pp. 35 – 72.
16. Owsiak S. (2008) Finanse publiczne. Teoria i praktyka (Public Finance. Theory and practice). – Warsaw: WN PWN, s. 836. (in Polish).
17. Pahl-Wostl C. (2009) A conceptual framework for analysing adaptive capacity and multi-level learning processes in resource governance regimes, *Global Environmental Change* 19, pp. 354 – 365.
18. Parysek J.J. (1996) Rozwój lokalny i lokalna gospodarka przestrzenna (Local development and local spatial). – Poznań: Bo-gucki Wydawnictwo Naukowe, s. 214. (in Polish).
19. Pelling M., Holloway A. (2006) *Legislation for mainstreaming disaster risk reduction*, Teddington: Tearfund. Available at: http://www.tearfund.org/webdocs/website/Campaigning/Policy%20and%20research/DRR%20legislation.pdf, 19 February 2014.
20. Tarno J.P. (2004) Samorząd terytorialny w Polsce (Local government in Poland). – Warsaw: LexisNexis, s. 317. (in Polish).
21. Urmonas A., Novikovas A. (2011) Europos vietos savivaldos chartijoje įtvirtintų principų įgyvendinimo vietos savivaldoje ir inkorporavimo nacionalinėje teisės sistemoje ypatumai (European Charter of Local Self-Government implementation of the principles enshrined in local governance and incorporation in the national legal systems). *Jurisprundencija*, vol. 18 Issue 3, pp. 1019-1034. Available at: http://web.ebscohost.com/ehost/pdfviewer/pdfviewer?vid=20&hid=112&sid=bc540c76-11ac-41fa-bae7-df54d5c89ea7%40sessionmgr114, 1 March 2014. (in Lithuanian).
22. Vidrevičienė I., Žukovskis J. (2010) Lietuvos kaimo bendruomenių bei seniūnijų tikslai ir funkcijos (The objectives and functions of Lithuanian rural communities and neighborhoods). *Lietuvos kaimo vietovių konkurencingumo stiprinimas: geroji patirtis 4-oji mokslinė - praktinė konferencija*. Akademija: LŽŪU, pp. 66 – 72. (in Lithuanian).
23. *Vietos savivalda ir bendruomenės Lietuvoje (Local self-government and community in Lithuania)*. (2010) Konferencijos medžiaga. Vilnius. Available at: http://vinilas.lt/lvbos/siuntiniai/Konferencija1.pdf, 19 February 2014. (in Lithuanian).
24. Xi Y., Tang F. (2004) HeXie Management Pattern of Intangible Assets in the Uncertain Environment. *Journal of Xi'an Jiaotong University (Social Sciences)*, pp. 42 – 46.
25. Xi Y., Shang Y. (2001) Harmony Management Thought and Contemporary Harmony Management Theory. *Journal of Xi'an Jiaotong University (Social Sciences)*, pp. 18 – 24.
26. Xi Y., Xiao H., Hong T. (2005) HeXie Management Theory and its New Development in the Principles. *Chinese Journal of Management*, pp. 23 – 28.

WELLBEING RESEARCH FOR RURAL DEVELOPMENT

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Abstract
This article aims to analyse the main features, importance and benefit of wellbeing research for rural development. Wellbeing research, which is becoming more and more important in social sciences discourse and its interrelations with rural development were analysed using analysis and synthesis of scientific literature, logic and systematic analysis, comparison and graphic modeling methods. The interest in the research significantly grew at the end of the 20th century and it is already recognized as a challenge and/or new instrument evaluating the progress and development of society. It should be noted that this direction of research can be adapted to different territorial levels. Wellbeing research is not only about the worldwide (macro level) wellbeing of nations, but also highlights specific features of smaller units like rural areas and their development (micro level). So when implementing the wellbeing research it is important to choose correctly whether objective or subjective wellbeing can be evaluated based on what positive or negative aspects it gives at the local level. This article deals with the main features of wellbeing research and what is common between this research and rural development as well as what benefit they give to rural communities and development. Research results show that benefit of wellbeing research for rural development is important because it allows to get information about the wellbeing situation of rural people, reveals existing problems and positive changes, gives an opportunity to observe how to improve the evaluation of wellbeing and informs rural actors about their role in the wellbeing research and their possible influence on the rural development.
Key words: wellbeing, objective wellbeing, subjective wellbeing, rural development.

Introduction

Historically, the wellbeing concept and its application have been transforming, and different stages of social development portrayed different characteristics of wellbeing of an individual and/or society (in different levels going from micro to macro). Looking at the evolution stages of wellbeing research, it is possible to notice that although economic growth was the biggest purpose of development, it also was a way to increase the choices available to people. The purpose of having those choices available was to enable people to find ways to live their lives better. This was an important reminder in the post-world war II years when the economics of development was strongly focused on reconstruction and capital accumulation. Much of the literature of the time simply equated development with economic growth (Measuring…, 2013). Unfortunately if economy may be growing this does not necessarily indicate that all people in all places within a national economy are experiencing positive development. For a long time the definition of wellbeing implied a possibility to earn a certain income as a means for satisfying at least minimal needs. Contemporary wellbeing does not only reflect the conditions under which people live (objective wellbeing) and allocate physical resources: a subjective perception of their wellbeing, including physical health, spiritual condition, feelings, values, and life priorities is gaining in importance (Diener, 1999; Kahn, 2002; Hird, 2003; McAllister, 2005; Vaznonienė, 2011). Consequently, the conducted analysis of the concept of wellbeing led to a most general definition that wellbeing means an overall satisfaction with life in various life domains, including subjective experience and objective life events.

Literature analysis reveals that there is no strong base of literature where the interconnection of wellbeing research and rural development is grounded. It is possible to find that research into rural communities' wellbeing is implemented, what indicators are monitored or methods applied. The benefit of wellbeing research which can be ensured for rural development or what is common between wellbeing research and rural development is still not revealed enough. So the shortage of wellbeing research interconnection with rural development allows to formulate such *scientific problem*: how the wellbeing research may reveal the progress of rural areas and its development. *The research object:* wellbeing research features enhancing rural development. *The aim of research* is to analyse the main features and benefit of wellbeing research for rural development. *The research tasks*: 1) to analyse the concept of wellbeing and wellbeing research evolution; 2) to determine the interconnection between wellbeing research and rural development and its benefit.

Materials and Methods

This article is prepared using descriptive and analytical approaches. The issue of this article wellbeing research for rural development - is analysed using the analysis and synthesis of scientific literature, logic and systematic analysis, comparison and graphic modeling methods.

Results and Discussion

The concept of wellbeing and its research

Since the late 20th century the issue of improving wellbeing among individuals and social groups has been gaining major importance in modern societies. The research into wellbeing is frequently identified with the research on living standards or living conditions which is usually based on objective criteria/indicators and often deals with separate areas of life. Such approach is rather limited and fails to offer a comprehensive measurement of wellbeing. Better wellbeing also means a more integrated society with significantly lower risk of poverty and social exclusion and no objective indicators of wellbeing, such as GDP per capita or unemployment rates can reveal the level of society integration.

Wellbeing is a concept which expresses the overall satisfaction with life in different life domains; it's more than good health, includes experience and objective life events; it's important both to individuals and society (McAllister, 2005). Most Western scholars (Diener, 2000; Camfield, 2005; Royo et al., 2006; Veenhoven, 2009, etc.) analyse wellbeing as one of the many scientific research areas. In scientific literature, considerable confusion is caused by English terminology and diverse interpretations of the wellbeing, which leads to numerous varieties of the concept of wellbeing (e.g. quality of life, welfare, happiness, life satisfaction, etc.) with their specific meaning. The analysis of the concept of wellbeing shows that it reveals the features and properties of material and cultural living conditions of people compared with a standard or a certain level and adequate satisfaction of those conditions.

When taking the overall approach, wellbeing might be valued as high or low. However, the value can be reduced due to negative phenomena or different situations. It might be stated, that society's life is socially determined, meaning that life among other people influences each personal experience and value of wellbeing. According to territorial aspect it is understood that rural people live in a specific area including various factors that influence their wellbeing like culture, environment, relations, social infrustructure etc.

S. Ventegodt et al. (2003), F. McAllister (2005), T.P easgood (2005) points out that evaluating the suitability of indicators for measuring wellbeing two things should be considered: 1) if indicators reflect the present situation (moment/static evaluation) and 2) whether they do not show old changes (recent life events/dynamic) both as with socio-economic factors. Due to their opinion the suitable methods enable to do better wellbeing research in rural areas and adopt them to purposive social groups. Eurobarometer research on wellbeing future (Wellbeing in 2030, 2011) emphasizes more policy decisions that will shape the future, both in terms of societal and personal wellbeing. It becomes significant not how people should live, but how they live now.

Broader wellbeing research did not start before the late 20th century when they stemmed from a growing interest in the wellbeing of an individual/society as well as the possibilities and the alternatives of a universal development. In the 1960s, wellbeing research appeared as a new area in social sciences. Analysing various wellbeing research reports it is possible to notice the transition from international/worldwide to national/regional/local level research. Local wellbeing research is usually related to local communities, place-based approach, targeted areas (with specific vulnerable, social risk groups, etc.) like attention in this article is given to rural development place in this field of research. For example the measurement of subjective wellbeing provides a valuable instrument for local authorities, their partners to understand and respond to local needs. So the main attention is paid to how to reduce negative outcomes for individuals and communities, including those whose circumstances make them vulnerable and those using services locally (Measuring…, 2013). This means that development of rural areas can be directly affected by the results of wellbeing research.

Analysis of literature (Fahey et al., 2003; Cagliero et al., 2011) allows to conclude that wellbeing research evolution is closely connected with wellbeing conceptualisation (Fig. 1).

Scientists and researchers (Diener and Diener, 2000; Gasper, 2004; Quality..., 2005, etc.) recognize that the classical approach to wellbeing or the traditional measurement approach is twofold: *objective and subjective.* But which one will be used in research depends on research aims and choice or possibility to implement the research. Despite that, whenever it is attempted to define what wellbeing for individual, social group or society is everyone can create his or her own formula of what a good life is for him/her with some specific components. Wellbeing is the first systematic presentation of this subject from both individual and collective perspectives. It provides a powerful overview of a concept which is becoming increasingly prominent in the social sciences and is essential reading for students of social policy, sociology and health studies.

In scientific literature *objective wellbeing* (Pavot and Diener, 1993; Hird, 2003; Gasper, 2005, etc.) is often perceived as normative part of the measurement, because usually majority of indicators are taken from statistical observations, various departmental institutions, etc. This concept mostly involves the evaluation of socio-economic indicators. Z.Norkus (2004) defined the objective wellbeing indicators as

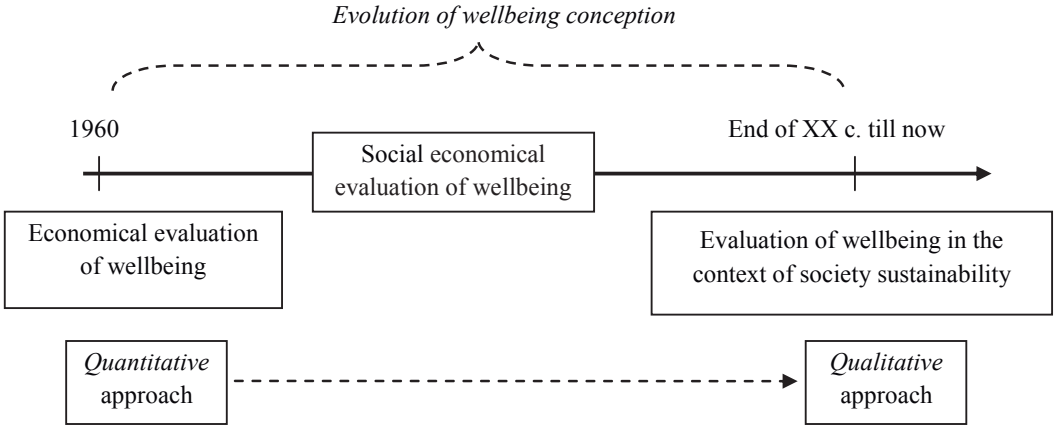

Figure 1. Evolution of wellbeing research (made by author).

„primary social goods“. It is accurate that objective indicators are described as data grounded by some criteria which reflect the situation of the whole society and their creation is usually determined by experts. Objective indicators are statistical variables that help to transform data into relevant information. Indicators have a meaning within defined conceptual frameworks and for specific analytical or administrative purposes. To provide meaningful information, they have to be interpreted in the context of these frameworks and purposes (Rural…, 2007). Following this idea it is noteworthy that wellbeing evaluation usually can have similarities with rural development indicators as we give priority to socio-economic context. Such wellbeing indicators can be powerful tools for analysis, planning and monitoring the rural development.

In the book "Rural Households' Livelihood and Well-Being" (2007) it is clearly stated that indicators on rural development need to be based on (1) published statistics that are (2) consistently collected in (3) comparable areas, using the (4) same unit of measurement and based on a (5) clear definition. Indicators should also be sensitive to changes and trends over time that can outline the future policy direction. In parallel, we can notice the same while talking about objective wellbeing indicators and their sets. Wellbeing usually includes environmental features, service availability, housing, safety, income and deprivation, health, culture, etc. In any case this means that implementing wellbeing research for rural development the priority is to improve socio-economic wellbeing, support the local human rights and minimize the vulnerability of the rural poor.

The most known representative of *subjective wellbeing* research Ed. Diener (2005) highlights that subjective wellbeing takes into account overall evaluations of personal life (positive and negative), the need of cognition, reactions to experience and its influence on present living. Also it is an overall satisfaction of one's own life and happiness. According to World Health Organization (Furmonavičius, 2001), subjective wellbeing can be defined as a distinction between personal expectations and a real opportunity to suceed in them. It shows that wellbeing, as a comparable construct, should be examined from different attitudes. Following some wellbeing reports (Robeyns et al., 2007; Wellbeing…, 2011; Measuring…, 2013), subjective wellbeing research helps to understand how a person's mood can have a positive or negative effect on their wellbeing. On the other hand when measuring subjective wellbeing data they take into account people's own aspirations and their evaluations of their experiences of development.

According to Z. Norkus (2004) in the context of wellbeing notion wishes reflect the subjective personal condition, whereas needs and interests are mostly influenced by psychological social environment. A subjective perception of wellbeing, which embraces the physical, psychological and social levels, shows that a judgment about the wellbeing is mostly affected by a subjective opinion of an individual rather than specific criteria/indicators used to measure wellbeing. Sometimes it is doubtful how reliable is subjective evaluation especially when wishing all received opinions to be attributed to whole. Therefore it is much more difficult to estimate subjective data than apply the objective indicators. Although objective indicators enable comparison between social groups or individuals, they are only one of the possible wellbeing research aspects, while subjective measurements represent the other aspect of such research, which offers a better reflection of quality indicators. The integration of both approaches allows to evaluate the possibilities for wellbeing research, to have a better understanding of it, and to ensure better wellbeing for individuals/social groups/the society.

Regarding the countries development level the wellbeing of individuals and social groups differs

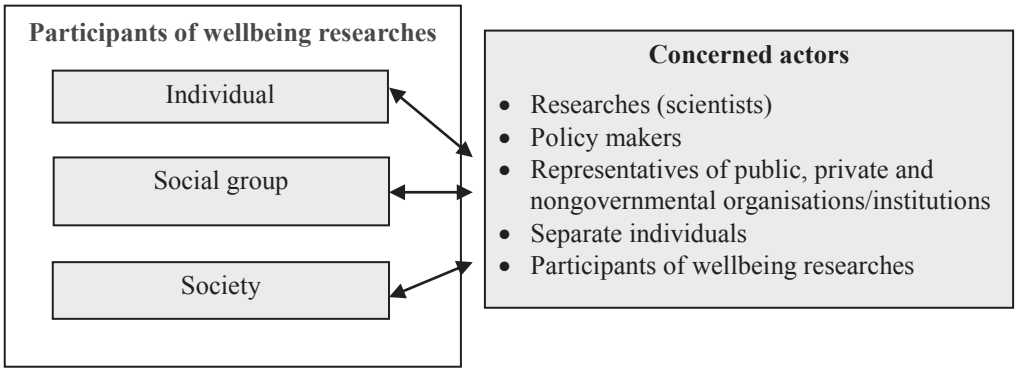

Figure 2. Participants and actors of wellbeing research (made by author).

although wellbeing domains are usually the same. Most scientific papers (Easterlin, 2003; Camfield, 2005; Measuring..., 2013, etc.) highlight such most important wellbeing or so called life domains: social, economic, environmental, cultural and political. Similarly it should be noted that in the process of rural development, especially in sustainability approach, almost the same domains are monitored. This proves that wellbeing research can be a part or element of rural development.

When implementing wellbeing research, it is important to be aware of whom it may concern (Fig. 2). According to this there is a need to identify the actors of wellbeing research because it allows to penetrate the purposive or priority groups whose wellbeing will be researched.

Figure reveals quite a big number of participants and actors of wellbeing research. This means that their intentions, aims or just interest related to wellbeing research can be various, but at the local level especially when talking about people in rural areas attention first of all is given to improving subjective wellbeing and then facing overall wellbeing.

Despite advantages/disadvantages of objective and subjective wellbeing research in scientific discourse, it is perceived that data of these both approaches are valuable. According to R.Veenhoven (2002, 2009), there are fewer issues caused by subjective measurement accuracy because respondents might be asked to provide their opinion directly after asking them. This gives an opportunity to measure and justify the indicators. Actually, for some wellbeing research purposes objective indicators are more suitable, whereas for others – priority is given to subjective opinion. Therefore, the concept of wellbeing as a social construct should combine the strengths of both objective and subjective research and assessment indicators which would allow to highligh drawbacks and eliminate them. So being aware of the features of wellbeing research, the next question – how the wellbeing research is related to rural development – is answered in the following part.

The role of wellbeing research in rural development

Rural development is a territorial, multisector and dynamic concept, concerned with a wide range of demographic, economic, social and environmental issues involving medium to long term changes. Wellbeing indicators were earlier discussed, so it is accurate that rural indicators thus should provide information on a variety of economic and social factors. However, there has also been a recent shift in thinking - away from the idea of rural development as a process mainly or entirely linked with economic growth - rather than based on increases in the wellbeing. While territorial income distribution is an important rural policy concern, disparities in social wellbeing and equivalence in standards of living cannot be properly assessed in income terms alone (Rural…, 2007). This is why it is important to say that the whole series of other aspects determining wellbeing should be taken into account, as the issue of a better wellbeing includes much more than only economic approach.

Wellbeing is one of the most important issues facing the world today and is central to the development of social policy for rural areas. Attitudes of wellbeing to individuals/social groups may vary not only between rural and urban territories, but also between rural areas. The concept of wellbeing in a rural setting primarily seeks to understand the interactions among the diversity of factors so that we might better understand individual, familial, and community trajectories.

M.A.Verdugo (2005) and his collegues, make the following assumptions for the necessity to study wellbeing in rural areas:

- wellbeing is important for all people, as well as for vulnerable groups, for now and future generations;
- in order to measure wellbeing, it is a must to understand how people value their own life and being;
- measurement of wellbeing reflects two approaches, how wellbeing is treated globally and individually (locally).

<table>
<tr>
<td rowspan="2">Wellbeing research levels</td>
<td rowspan="2">➢ Human
➢ Community/group
➢ Local
➢ Regional
➢ National
➢ International</td>
<td>Indigenous indicators with “bottom up” approach</td>
<td rowspan="2">Rural development</td>
</tr>
<tr>
<td>Endogenous indicators with “top bottom” approach</td>
</tr>
</table>

Figure 3. Interconnection of wellbeing research and rural development (made by author).

This points out that the existing territorial differences among rural areas have an impact on their development trends. According to the idea that wellbeing research can influence rural development, there can be a detailed interconnection between these two issues (Fig. 3). This figure indicates how the wellbeing research levels are related to the main rural areas management and development approaches, as well as how these two approaches become a part of wellbeing research levels. As it was mentioned in the 2013 OECD Global forum on development (Measuring…, 2013) the careful integration of a bottom-up approach human/individual wellbeing methodology may avoid the worst excesses of top-down approach, paternalistic approaches which tell people what they need and what they are going to be given to address that need.

Following the ideas from the report about local wellbeing (Steuer and Marks, 2008), a three-tiered approach is recommended for measuring wellbeing at the local level:

1) universal level;
2) domain level;
3) targeted level.

It should be noted that both the *universal* and *domain* levels are designed to fit within the new performance context for local government. Measurement at the *targeted* level will focus more on the local context and the extent to which measures can be disaggregated to specific target groups. Such approach shows up to which level measure wellbeing depends on the rationale for collecting new information and the potential for decisions and actions to be taken as a result of the findings in each local area.

The report of local communities' wellbeing (Steuer and Marks, 2008) provides thinking of wellbeing, including some key dimensions of how people experience their lives at a local level:

- how they feel about their own lives (for example, health, work, financial circumstances);
- how they feel about those around them (for example, friends, neighbours, community);
- how they feel about where they live (for example, neighbourhood quality, accessibility, safety).

As it is pointed out in the recent reports of wellbeing research (Ramsey et al., 2006; Quality…, 2006; Well-being, 2011; Quality…, 2013), the key aspects of wellbeing research enhancing rural development should relate to the focus:

- on efforts to tackle poverty, social exclusion and integrate people with disabilities;
- strengthening the working hours directive, or other policies that could lead to the reduction of working hours and improvement of work–life balance;
- maintaining the quality of public services in the face of austerity, particularly, it seems, in southern Europe;
- recognizing the importance of relationships to people's well-being. For example, social support is the weakest in countries in the liberal cluster. It is proposed that the unintended well-being consequences of certain economic policies should be considered.

All above-mentioned reveals the idea that the fact *where* and *how* rural people live is very important both for wellbeing research and for rural development progress. Being aware of static/present moment gives opportunities to make a better future living.

Following all above-mentioned wellbeing research provides a benefit for rural development in several ways – by:

- giving priority to bottom up (↑) approach (or place-based approach) rather than to top bottom (↓);
- allowing to see how both wellbeing and rural development indicators change over time;
- providing cognition about the overall wellbeing of local community and separate life domains;
- giving information not only about existing problems, but also about individuals, social groups (especially more vulnerable), deprived areas and their improved lives (positive local change);
- revealing ways of socio-economic progress where the needs of everyone are recognized;
- emphasizing the importance of the research results feedback to respondents, this also makes it easier for people to get involved in

their communities, highlights active role of individuals;
- showing the possibility of improving local surroundings;
- emphasizing for the policy makers which life domains of local community should be solved at first;
- the growing interest in this research field in academic and policy practice is based on how to assess wellbeing and how to monitor progress in rural population;
- showing that rural development, rural progress is important not only to local/targeted (micro) level, but it has impact on overall (macro) development of the society.
- interrelations between wellbeing research and sustainable development of rural society prove overall human rights and freedom implementing.

It is obvious that wellbeing research for rural development is quite open and challenging issue. It should be pointed out that this research highlights not only the scientific importance but also practical and political one. These given ideas also prove that measuring wellbeing can also support local authorities and their partners in assessing 'real' progress, especially in sustainability approach by directly capturing people's experience of their lives rather than using proxy indicators (Steuer, 2008; Sustainable..., 2014). It all conforms to the idea expressed by the concept of sustainable development – better wellbeing must be an ultimate purpose to everyone now and for generations to come.

Conclusions

1. In general terms, wellbeing can be defined as an overall satisfaction of life or satisfaction with different life domains, including subjective experience and objective life events. Objective wellbeing is measured using objective criteria/ indicators that are usually based on the statistical information provided by official statistics and various departmental institutions. However, the definition of subjective wellbeing is much more complex because its description varies and it is reflected in a number of concepts.
2. There are observed quite different positive and negative features of wellbeing, especially following objective and subjective approaches. It should be perceived that these both approaches are valuable for several reasons: scientific, practical, methodological and political.
3. Revealing the interconnection between wellbeing research and rural development is indeed important not only in the scientific context, but also for local authorities or local government. It gives the direction of how to observe changes both in wellbeing research at the local level and rural development in whole.
4. The benefit of wellbeing research for rural development is important in many ways. It enables to know the wellbeing situation of rural people, reveals existing problems as well as positive changes, gives opportunity to observe how to improve the evaluation of wellbeing, and informs rural actors about their role in wellbeing research and their possible influence on rural development.

References

1. Cagliero R., Cristiano S., Pierangeli F., Tarangioli S. (2011) Evaluating the Improvement of Quality of Life in Rural Areas. *Ancona - 122nd EAAE Seminar*. Available at: http://ageconsearch.umn.edu/bitstream/99427/2/caglierocristianopierangelitarangioli.pdf, 12 February 2014.
2. Camfield L. (2005) Researching Quality of Life in Developing Countries. *Newsletter of the ESRC Research Group on Well being in Developing Countries*. Retrieved July 3. Available at: http://www.welldev.org.uk/news/newsletter-april-05.htm, 20 January 2014.
3. Diener Ed., Suh E.M., Lucas R.E., Smith H.L. (1999) Subjective Well-Being: Three Decades of Progress. *Psychological Bulletin*, Vol. 125, No. 2, pp. 276 – 302.
4. Diener Ed., Diener B. (2000) New directions in subjective well-being research: the cutting edge. *Indian Journal of Clinical Psychology.* Vol. 27 pp. 21 – 33.
5. Diener Ed. (2005) *Guidelines for National Indicators of Subjective Well-Being and Ill-Being*. November 28. Available at: http://s.psych.uiuc.edu/~ediener/Documents/Guidelines_for_National_Indicators.pdf, 20 January 2014.
6. Easterlin R.A. (2003) Building a Better Theory of Wellbeing. *IZA Discussion Paper No. 742*. Available at: http://ssrn.com/abstract=392043, 23 February 2014.
7. Fahey T., Nolan B., Whelan Ch.T. (2003) *Monitoring quality of life in Europe*. European Foundation for the Improvement of Living and Working Conditions, Office for Official Publications of the European Communities, Luxembourg, 91 p.
8. Furmonavičius T. (2001) Gyvenimo kokybės tyrimai medicinoje (Quality of life researches in medicine). *Biomedicina*. T. 1, Nr. 2, gruodis, pp. 128 – 132. (in Lithuanian).

9. Gasper D. (2004) Human Well-being: Concepts and Conceptualizations. *Discussion Paper No. 06*. Available at: http://www.wider.unu.edu/stc/repec/pdfs/rp2004/dp2004-06.pdf, 28 January 2014.
10. Gasper D. (2005) Subjective and objective well-being in relation to economic inputs: puzzles and responses. *Review of Social Economy*, 1470-1162, Volume 63, Issue 2, pp. 177 – 206.
11. Hird S. (2003) What is wellbeing? *A brief review of current literature and concepts*. NHS Health Scotland. Available at: http://www.phis.org.uk/doc.pl?file=pdf/What%20is%20wellbeing%202.doc, 28 January 2014.
12. Kahn R.L., Juster F.T. (2002) Wellbeing: concepts and measures. *Journal of Social Issues*, 2002 58 (4), pp. 627 – 644.
13. McAllister F. (2005) Wellbeing Concepts and Challenges. *Discussion paper prepared for the Sustainable Development Research Network.* Sponsored by Defra, 22 p.
14. Measuring Well-being for Development (2013) *2013 OECD Global Forum on Development. Discussion Paper for Session 3.1*. Available at: www.oecd.org/site/oecdgfd/, 20 February 2014.
15. Norkus Z. (2004) Ar galime gyventi geriau? Velfarizmas ir jo alternatyvos (Can we live better? Welfarism and its alternatives). *Politologija*, Nr: 4 (36), pp. 3 – 39. (in Lithuanian).
16. Pavot W., Diener Ed. (1993) Review of the Satisfaction with Life Scale. *Psychological Assessment*. Vol. 5, No. 2, pp. 164 – 172.
17. Peasgood T. (2005) Modelling Subjective Well-being. *Paper presented at BHPS – 2005 Conference*, Essex. Centre for Well-Being in Public Policy, University of Sheffield, 35 p. Available at: file:///C:/Users/Bernardas/Downloads/9c960525669012bb3e.pdf, 20 February 2014.
18. Quality of Life and Well-being: Measuring the Benefits of Culture and Sport. *Literature Review and Thinkpiece.* (2005) Scottish Executive Social Research, 160 p. Available at: http://www.scotland.gov.uk/Resource/Doc/89281/0021350.pdf, 15 January 2014.
19. Quality of Life Survey 2006 (2006) Quality of life in New Zealands' large urban areas. Available at: http://www.bigcities.govt.nz/surveys06.htm, 15 January 2014.
20. Quality of life in Europe: Subjective well-being (2013) *3rd European Quality of Life Survey*. European Commission. Luxembourg: Publications Office of the European Union. 128 p. Available at: http://www.eurofound.europa.eu/pubdocs/2013/59/en/1/EF1359EN.pdf, 20 February 2014.
21. Ramsey D., Beesley K. (2006) Rural Community Well-being: The Perspectives of Health Care Managers in Southwestern Manitoba, Canada. *Journal of Rural and Community Development* 2, pp. 86 – 107.
22. Robeyns I., Veen R.J. (2007) Sustainable quality of life: Conceptual analysis for a policy-relevant empirical specification. *MNP Report 550031006/2007*. Netherlands Environmental Assessment Agency, 99 p.
23. Rural Households' Livelihood and Well-Being (2007) The Wye Group Handbook. *Statistics on Rural Development and Agriculture Household Income.* United Nations. 533 p.
24. *Rural Well-being* (2014) Available at: http://www.ndsu.edu/hdfs/research_and_projects/rural_well_being/, 8 March 2014.
25. Sharpe A., Smith J. (2005) Measuring the Impact of Research on Well-being: A Survey of Indicators of Well-being. *CSLS Research Report Number 2005-02.* Centre for the Study of Living Standards for the Prime Minister's Advisory Council on Science and Technology, 119 p.
26. Steuer N., Marks N. (2008) *Local Wellbeing: Can We Measure It*? Department for Communities and Local Government. Available at: http://s.bsd.net/nefoundation/default/page/file/c6f4c88b25b2696984_o7cm6ts1z.pdf, 8 March 2014.
27. *Sustainable Quality of Life* (2014) Available at: http://sustainablequalityoflife.org/, 8 March 2014.
28. Vaznonienė G. (2011) Subjektyvi gerovė ir socialinė atskirtis: pagyvenusių žmonių atvejis (Subjective wellbeing and social exclusion: a case of elderly people) (Daktaro disertacija) (Doctoral dissertation). Kauno Technologijos universitetas. 214 p. (in Lithuanian).
29. Veenhoven R. (2002) Why Social policy needs subjective indicators. *Social Indicators Research*. Vol 58, pp. 33 – 45.
30. Veenhoven R. (2009) Well-Being in Nations and Well-Being of Nations. Is There a Conflict Between Individual and Society? *Soc Indic Res*. 91, pp. 5 – 21.
31. Ventegodt S., Merrick J. (2003) Lifestyle, Quality of Life, and Health. *The Scientific World Journal*, pp. 811 – 825.
32. Verdugo M.A., Schalock R.L., Keith K.D., Stancliffe R.J. (2005) Quality of life and its measurement: important principles and guidelines. Journal of Intellectual Disability Research. Volume 49, Part 10, pp. 707 – 717.

33. Well-being (2011) *Aggregate report. Eurobarometer Qualitative studies*. Available at: http://ec.europa.eu/public_opinion/archives/quali/wellbeing_final_en.pdf, 18 February 2014.
34. Well-being in 2030 (2011) *Aggregate report. Eurobarometer Qualitative studies*. Available at: http://ec.europa.eu/public_opinion/archives/quali/wellbeing_aggregate_en.pdf, 18 February 2014.

CULINARY HERITAGE IN LATVIAN MUNICIPALITIES AND ITS ROLE IN THE DEVELOPMENT OF ENTREPRENEURSHIP

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Abstract
The municipalities of Latvia are different in terms of business development level. Latvia's regions are grouped into clusters based on several indicators: number of economically active individual merchants and commercial companies per 1000 capita, territorial development index, and proportion of working-age population. In addition to the business indicators, the following tourism indicators were selected: number of recreational establishments, number of bed-places, number of individual rooms, number of farms and individual merchants making use of culinary heritage. All these indicators are statistically significant for clustering municipalities. The clustering was performed by employing K-Means clustering and using the data processing programme SPSS. All Latvia's municipalities were divided into four clusters based on the business development level and the level of exploitation of tourism infrastructure and culinary heritage. The analysis results enable conclusions to be made that a positive correlation exists between the business environment development level, and the level of use of tourism and culinary heritage. Culinary heritage is an important additional possibility for fostering business and economic growth in Latvia's municipalities. A linear multi-factor regression equation was obtained, which associated the revenues of the operating budget of a municipality with the following statistically significant factors: population density, territorial development index, expenditure on economic activity development, number of economically active entrepreneurs and commercial companies, number of tourism establishments, and number of enterprises dealing with culinary heritage. The analysis of regression equation coefficients points to the positive effects of all the factors included in the equation on the revenues of the basic budget of a municipality.
Key words: entrepreneurship, municipalities, clusters, rural tourism, culinary heritage.

Introduction

After long discussions, the administrative and territorial reform in Latvia began with passing the Law on Administrative Territories and Populated Areas (Law on Administrative Territories, 2008). In the result of the reform, 110 amalgamated municipalities emerged in the rural areas of Latvia, which were very diverse in terms of area, number of residents, population density, economic characteristics, and development level. The municipalities occupy 98.9% of the country's territory, and 49% of Latvia's population live there (Reģionu attīstība Latvijā, 2012). The first results, which may be analysed, are seen four years after the reform.

The aim of the paper focuses on assessing the development of tourism in the municipalities, especially emphasising the use of culinary heritage as a component of cultural heritage (Freijers, 2011; Simkova, 2013; Durands, 2007; Tourism trends, 2012; Wilson, 2007). The research tasks were: to group Latvian regions into clusters based on several indicators of business activities; to verify the correlation between the business environment development level and the level of use of tourism and culinary heritage; to obtain linear multi-factor regression equation. The paper continues research about cultural heritage as an additional possibility for economic growth in municipalities (Jeroscenkova et al., 2013).

The research results will be important for municipalities' development plans.

Materials and Methods

Cluster analysis was employed to analyse Latvia's rural municipalities. First of all, statistically significant factors were selected for the cluster analysis. It was carried out by means of dispersion analysis, and only the factors that were statistically significant (Sign.<0.05) and did not repeat themselves were selected out of 24 initial factors (Reģionu attīstība Latvijā, 2012; Central Statistical Bureau, 2012).Thus, the following factors were selected: area, number of residents, population density, territorial development index, number of tourist accommodations, number of bed-places, number of individual rooms, number of enterprises dealing with culinary heritage, and number of commercial companies per 1000 capita. The cluster analysis was performed by employing K-Means clustering and using the data processing programme SPSS.

In addition, a linear multi-factor regression equation was obtained (Krastiņš, 2003), which associated the revenues of the operating budget of a municipality with the following statistically significant factors: population density, territorial development index, expenditure on economic activity development, number of economically active entrepreneurs and commercial companies, number of tourism establishments, and number of enterprises dealing with culinary heritage. The analysis of regression equation coefficients points to the positive effects of all the factors included in the equation, on the revenues of the operating budget of a municipality.

Culinary heritage is an important additional opportunity for fostering entrepreneurship and economic growth in Latvia's municipalities. (Kulinārais mantojums lauku tūrismā, 2013; Lauku ceļotājs, 2013). The analysis of culinary heritage enterprises in municipalities was performed by means of Cross tabulation analysis in the SPSS data processing system.

Results and Discussion

Four clusters were obtained in the cluster analysis. The clusters differed from each other in cluster centre coordinates, i.e. factor numerical values that determine the centre of clusters (Table 1). So, the first cluster's large area, large number of residents, high population density, and high territorial development index indicate the economically strong municipalities in this cluster (Table 1). Entrepreneurship is also well-developed there, which is confirmed by the number of and commercial companies per 1000 capita. The tourism factors have relatively higher values, and it also points at the progress in tourism development in the cluster's municipalities. Cluster 1, which contains 16 municipalities, is a cluster of economically strong municipalities with well-developed entrepreneurship and tourism. The most characteristic municipalities of this cluster are Aluksne, Bauska, Cesis, Dobele, Gulbene, Kuldiga, Limbazi, Madona, and Sigulda. Cluster 2, which includes only 4 municipalities, is an economically medium-developed cluster, but it has well-developed entrepreneurship and very well-developed tourism. This cluster includes the following municipalities: Ogre, Rezekne, Talsi, and Tukums. Cluster 3 has the greatest number of municipalities, 61 in total, and economic under-development and insufficient tourism development are characteristic of it. This cluster is represented by the municipalities of all regions, for instance, Akniste, Aloja, Baltinava, Cibla, Durbe, Ergli, Jaunpils, Koceni, Karsava, Krustpils, Lubana, Nereta, Rugaji, Skrunda, Varkava, Vilaka, Zilupe, and others. In this cluster, the municipalities are equally distributed among the regions – 13-14 municipalities in a region – except Vidzeme region with 20 municipalities. Cluster 4 has 29 economically strong municipalities, however the tourism is poorly developed in it, even though entrepreneurship is well-develop there. For instance, the following municipalities belong to this cluster: Adazi, Aizkraukle, Auce, Babite, Balvi, Burtnieki, Iecava, Kandava, Lielvarde, Livani, Ludza, Ozolnieki, Preili, Salacgriva, Smiltene, and Vecumnieki.

A comparison of distances between the final cluster centres shows that Cluster 2 differs most from Clusters 3 and 4 as well as Cluster 1 from Cluster 3 (Table 2).

Table 1

Numerical values of the coordinates of cluster centres

Factors	Clusters			
	1	2	3	4
Area	1094.63	1618.00	391.79	550.55
Number of residents	23314.19	34058.25	4449.43	10530.10
Population density	44.30	24.45	15.55	39.58
Territorial development index	0.12	-0.15	-0.38	0.28
Number of tourist accommodations	7.38	11.75	2.13	4.03
Number of bed-places	255.75	374.25	77.02	161.10
Number of individual rooms	99.06	167.00	24.05	57.07
Number of culinary heritage enterprises	0.56	3.00	0.26	0.72
Number of commercial companies per 100 capita	54.33	57.03	65.73	56.82

Table 2

Distances between Final Cluster Centres

Cluster	1	2	3	4
1	0	10757.690	18878.871	12796.077
2	10757.690	0	29636.044	23553.576
3	18878.871	29636.044	0	6083.475
4	12796.077	23553.576	6083.475	0

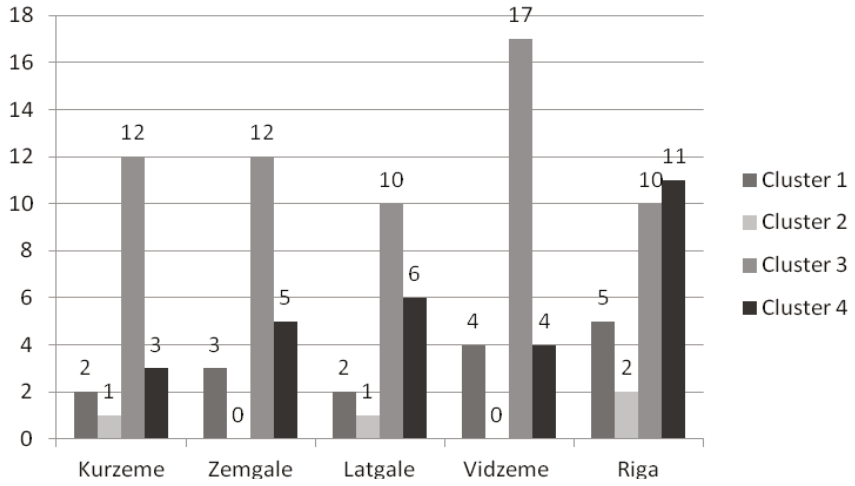

Figure1. Regional distribution of the municipalities by cluster.

In Cluster 1, in the economically well-developed municipalities where tourism is well-developed, - most of the municipalities are located in Riga and Vidzeme regions, 5 and 4, respectively. In Cluster 4, whose municipalities are also economically well-developed, but their tourism is insufficiently developed, - most of the municipalities are located in Pieriga (11), Latgale (6), and Zemgale (5) regions. The economically poorly-developed municipalities with underdeveloped tourism, i.e. Cluster 3, in their turn, are mainly represented by Vidzeme (17), Kurzeme (12), and Zemgale (12).

The distribution of the municipalities by region reveals the following picture:

To perform a more detailed analysis on how the factors included in the regression analysis affect the economic situation in a municipality, let us make a regression analysis (Krastiņš, 2003). Municipality operating budget revenue, LVL capita^{-1}, was chosen as the dependent variable, while the independent variables are all the factors that were included in the cluster analysis. The regression equation obtained is not statistically significant, as the multi-factor correlation coefficient R=0.244 and the determination coefficient R^2=0.060 at a significance level p= 0.375 > 0.05. To enhance the regression equation, let us exclude the following several factors: area, number of residents, territorial development index, number of bed-places, number of individual rooms and number of commercial companies per 1000 capita. The resulting multi-factor linear regression equation is better, as the multi-factor correlation coefficient R=0.387 and the determination coefficient R^2=0.150 at a significance level p= 0.002 < 0.05.

The table presenting the multi-factor linear regression equation's regression coefficients and the numerical value of the free member shows both the coefficients' numerical values and their standard significance level and confidence interval.

Thus, the multi-factor linear regression equation is as follows (Krastiņš, 2003):

$$Y = 579.72 + 0.583\ x_1 + 0461\ x_2 + 0.688\ x_3 - 1.920\ x_4,$$

where

Y – revenues of the municipality operating budget, LVL capita^{-1};

x_1 – population density, people km^{-2};

x_2 – expenditures on economic activity, LVL capita^{-1};

x_3 – number of tourist accommodations in the municipality;

x_4 – number of culinary enterprises in the municipality.

The significance level exceeds 0.05 only for two factors – the number of tourist accommodations and the number of culinary enterprises –, yet, given the fact that these factors are very important for our analysis, they remain in the equation.

The regression coefficients are positive for all independent factors, except the number of culinary enterprises. It means that as, for instance, the population density rises by a unit (people km^{-2}), a municipality's operating budget revenue increases by 0.583 units (LVL capita^{-1}) (Table 3) or an increase in the number of tourist accommodations by 1 leads to an increase in the municipality's operating budget revenue by 0.688 units (LVL capita^{-1}).

However, an increase in the number of culinary enterprises by 1 results in, on average, a decrease in the municipality's operating budget revenue by 1.920 units (LVL capita^{-1}). It means that the development of culinary heritage requires investment from the municipality's budget and does not generate instant gains. Nevertheless, it has to be mentioned that given the regression coefficients' confidence intervals, an increase in the number of culinary enterprises by 1 may lead both to a decrease in the operating budget

Table 3

Regression coefficients

	Unstandardized Coefficients		Sig.	95% Confidence Interval for B	
	B	Std. Error		Lower Bound	Upper Bound
Constant	579.721	16.568	0.000	546.870	612.572
Population density	0.583	0.290	0.047	0.007	1.159
Number of tourist accommodations	0.688	2.464	0.781	-4.197	5.573
Expenditures on economic activity	0.461	0.120	0.000	0.223	0.698
Number of culinary enterprises	-1.920	9.684	0.843	-21.122	17.282

Table 4

Regression coefficients

	Unstandardized Coefficients		Sig.	95% Confidence Interval for B	
	B	Std. Error		Lower Bound	Upper Bound
Constant	581.060	14.044	0.000	553.219	608.901
Population density	0.589	0.287	0.043	0.020	1.157
Expenditures on economic activity per capita	0.462	0.119	0.000	0.227	0.697

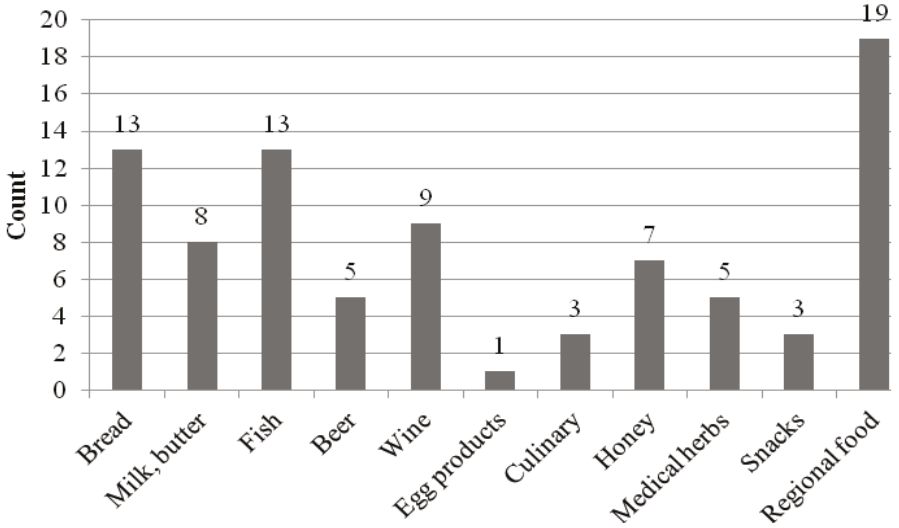

Figure2. Culinary heritage enterprises in the regions.

revenue by 21.12 units and to an increase by 17.28 units. It simply means that culinary enterprises are a relatively new phenomenon in Latvia's municipalities and this process has to stabilise, only then stable and significant conclusions may be made.

If the independent variables whose p>0.05 remain in the regression equation, the following multi-factor regression equation (correlation coefficient R= 0.386, determination coefficient R^2 = 0.149, p=0.000<0.05) is obtained:

$$Y = 579.72 + 0.583\ x_1 + 0461\ x_2$$

where

Y – revenues of the municipality operating budget, LVL capita^{-1};

x_1 – population density, people km^{-2};

x_2 – expenditures on economic activity, LVL capita^{-1}.

As shown, the regression coefficients' numerical values have not significantly changed (Table 4) and their interpretation is the same as before.

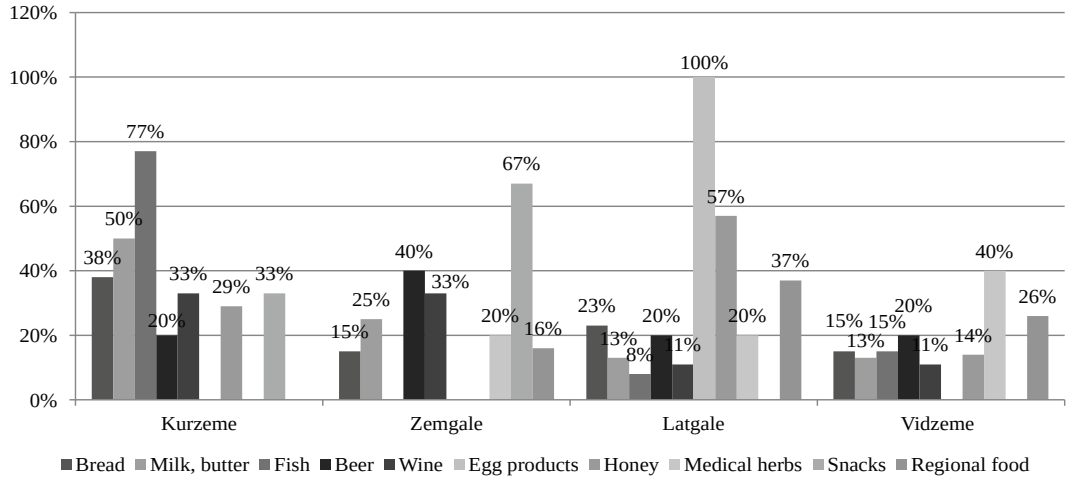

Figure3. Culinary heritage enterprises in the regions of Latvia by specialisation.

Culinary heritage in the municipalities and subsequently in the regions was assessed based on the enterprises offering culinary heritage services (Kulinārais mantojums lauku tūrismā, 2013). The distribution by kind of culinary heritage was as follows:

There were mostly represented local culinary heritage enterprises (19), while the next most popular were bread producers and fish product producers.

Differences were observed among the regions. In Kurzeme, for instance, fish product producers (10) were the most popular, while dishes of the municipality were popular in Latgale (7), Vidzeme (5), and Kurzeme (4).

The greatest number of enterprises dealing with culinary heritage is observed in the following municipalities: Engure and Talsi (6-7 enterprises), Bauska, Plavinas, and Tukums with 3 enterprises in each, two enterprises are available in 9% and one in 14.5% of the municipalities, whereas not a single enterprise operates in 72% of the municipalities.

Conclusions

1. Culinary heritage is an important additional opportunity for fostering entrepreneurship, especially tourism, and economic l growth in Latvia municipalities.
2. By employing cluster analysis, the municipalities of Latvia may be grouped into 4 clusters: a cluster of economically strong municipalities with well-developed entrepreneurship and tourism (16 municipalities); a cluster of economically medium-developed municipalities with well-developed entrepreneurship and very well-developed tourism (4 municipalities); a cluster of municipalities having underdeveloped business activity and insufficiently developed tourism (61 municipalities); the fourth cluster has economically strong municipalities with well-developed entrepreneurship, but tourism is relatively underdeveloped there (29 municipalities).
3. The regression analysis showed that mainly the density of population and the expenditure on economic development positively affect a municipality's operating budget revenues. However, the numbers of tourist accommodations and culinary enterprises in a municipality make no explicit effect on the municipality's budget revenues; yet, it might emerge after the process of rural tourism development stabilises.
4. Latvian culinary traditions are rich and alive. The regions insufficiently promotes the advantage of preparing traditional dishes daily. Recipes and cooking techniques have survived and evolved - they were not artificially restored. It remains to introduce them into guest houses, restaurants, and other food menus, making them increasingly demanded.
5. The culinary heritage of Latvia requires an extensive and coordinated campaign that includes both recipe collection and host/hostess training and experience, the introduction of traditional dishes and catering menus, as well as marketing and awareness efforts.

References

1. Law on Administrative Territories and Populated Areas (2008) Available at: http://likumi.lv/doc.php?id=185993, 21 March 2013.
2. Reģionu attīstība Latvijā (Regional Development in Latvia) (2012) VARAM, VRAA, Rīga, 41, 151 – 154. lpp. (in Latvian).

3. Freijers V. (2011) Tūrisma mārketings (Tourism Marketing). Rīga: Biznesa Augstskola Turība, 620 lpp. (in Latvian).
4. Simkova E. (2013) Cultural Tourism as an Important Tool for Sustainable Development in Czech Republic. Advances in Environmental Science and Sustainability, Available at: http://www.wseas.us/e-library/conferences/2012/Sliema/NACGURES/NACGURES-17.pdf, 15 July 2013.
5. Jeroscenkova L., Kruzmetra M., Rivza B. (2013) Enhancing the Competitiveness of Tourism Through Cultural Heritage as aTourism Product, RURAL DEVELOPMENT 2013, THE SIXTH INTERNATIONAL SCIENTIFIC CONFERENCE PROCEEDINGS, Volume 6, Book 1, Aleksandras Stulginskis University. Lithuania, pp. 163 – 167.
6. Durands G. (2007) Multifunctionality and Rural Tourism: a perspective of farm diversification. Journal of International farm management, Vol. 4, No1., pp. 2 – 23.
7. Tourism trends. (2013) Available at: http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/Tourism_trends, 8 July 2013.
8. Wilson G.A. (2007) Multifunctional Agriculture. A Transition Theory Perspective CABI, UK, USA. 364 p.
9. Central Statistical Bureau of the Republic of Latvia: tourism statistics (2012) Available at: http://www.csb.gov.lv/dati/statistikas-datubazes-28270.html, 21 March 2013.
10. Krastiņš O. (2003) Ekonometrija (Econometrics). Rīga: LR CSP, 207 lpp. (in Latvian).
11. Kulinārais mantojums lauku tūrismā (Culinary heritage of rural tourism) (2013) Available at: http://www.celotajs.lv/, 21 March 2013. (in Latvian).
12. Par lauku tūrisma attīstības tendencēm. (Rural tourism development trends) (2013) Available at: http://www.celotajs.lv/news/list/p?lang=lv, 21 March 2013. (in Latvian).

ANALYSIS OF THEORETICAL AND PRACTICAL ASPECTS OF YOUTH LONG-TERM UNEMPLOYMENT IN LATVIA

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Abstract
Unemployment and labour market adjustments have featured prominently among the problems of transitional economies. However, the position of young people and their transition from school to work in these new market economies has been virtually ignored. This paper deals with long-term youth unemployment problems and their integration into the labour market as viewed by different authors. The authors consider that the youth long-term unemployment is a global problem. Also, there are analysed statistical data on youth long-term unemployment, and a forecast of the youth unemployment rate for the 1st quarter of 2014 is made.
The weakening of the global recovery in the years 2012 and 2013 has aggravated the youth employment crisis when there were no free jobs with adequate requirements for people without education and professional skills. The current situation promotes the trend that was already evident before the economic crisis. Most of young people are now turning to available part-time jobs or choose to study only.
The author considers that the youths who have access to different resources will find more stable jobs or make their own businesses after unemployment than those lacking such different kinds of support. In building the education and employment decisions in the transition from school to work, there is a strong evidence of the importance of youths making good initial career decisions and an enduring effect of academic achievement on labour market and education outcomes.
Key words: youth long-term unemployment rate, labour market, integration in the labour market.

Introduction

In this paper, the author draws attention to long-term youth unemployment examination, as it is believed that it is today's major problem for future development, which will affect both national and global economic growth, and intensification of the globalisation process.

Also substantial is the new generation's successful integration into the labour market, creation of innovative ideas and the realisation of the business, which will provide the new generation's future prospects internationally. The negative aspect contributing to the world's economic globalisation is the outflow of youth's intellectual capital to abroad, which actually takes away Latvia's young professionals and decreases the evolution of innovative products and services. Nowadays it is known that the realisation of innovative products and services is one of the preconditions for successful development of business at international level, which provides the greatest part of the company's income.

The global youth unemployment problem is one of the main tasks for the European Parliament to deal with. There is a need to deal with this problem at the European level because there have been a lot of unemployed young people in Spain, Greece, Italy and the Baltic States, too, for already 5 years. And the crisis is not the main obstacle because it began 5 years ago and politicians are considering that the crisis has already ended. The main problem is globalisation, not the economic crisis, which made that kind of problem at the European and world's level.

More information on scientific research on youth long-term unemployment and this problem can be found globally. In Latvia, economists and politicians think that there are no serious problems with youth unemployment and unemployment at all. They are writing in reports that there is a high possibility to find a normal and well paid job without problems, but they are not seeing the truth. In Latvia, especially in the countryside, problems with youth unemployment are serious, there is no possibility to work and develop entrepreneurship because of low demand. To develop entrepreneurship, young people have to find a new way how to deal with demand problems, for example, they need to export their production or to produce a very special service with an innovative idea.

The aim of the research is to evaluate and compare experience and approaches regarding the youth long-term unemployment problem in Latvia.

The following tasks are set to achieve the aim:

1) To evaluate the theoretical aspects of the long-term unemployment of youth from different authors;
2) To analyse the youth long-term unemployment trends and dynamics in Latvia.

Materials and Methods

Research methodology: the methods of analysis, synthesis and logical construction, statistical data analysis, as well as scientific discussion were applied to reach the aim.

Theoretical framework of the research: the research is based on other scientific research in the

economic field, statistical information provided by the European Statistical Office and the Central Statistical Bureau of Latvia.

The data obtained in the research were statistically processed by the MS Excel program. The time series analysis was performed for less than 25 year-old unemployed youths for the period from the 3rd quarter of 2011 to the 1st quarter of 2014.

Results and Discussion

Trends of long-term youth unemployment. Youth unemployment has been a central focus of transitions research since the 1980s, with a significant number of studies focusing on cross-national differences in unemployment levels, as well as on the impact of active labour market policies designed to facilitate employment access (Blanchflower et al., 2000).

Long-term youth unemployment is a major problem. As a difficult economic climate persists, young people are increasingly facing longer spells out of the labour market. Whilst we would expect both long-term and total youth unemployment to reduce once the economy returns to growth and the supply of jobs is increased, many of those entering the labour market over the past few years and until recovery begins face heightened challenges. There is a danger that even those who in ordinary circumstances would be expected to make successful transitions into employment will become distanced from the labour market. Moreover, there is a danger that cyclical unemployment becomes a structural problem (Short-term crisis…, 2012).

A rise in youth unemployment during a recession is to be expected. Youth unemployment is typically higher than adult unemployment regardless of economic conditions, as young people face higher rates of labour market turnover and spend time moving between jobs before settling on a stable career path. In a recession this gap is amplified because young people are more likely to lose their jobs, and new (young) entrants to the labour market face tougher competition for jobs.

The author considers that the youth long-term unemployment problem depends not only on youth and their professional skills but on the economic situation of the region where they live and work.

According to Arumlampalam, evidence suggests that young people suffer a “wage penalty” (the difference between the actual wage earned and that earned by comparable people who have not experienced unemployment) on their return to work (Short-term crisis…, 2012).

Authors, Gregg and Tominey, have calculated the wage penalty to be as much as 13-21 per cent by age 42, but noted that this penalty could be minimised to 9-11 per cent if repeat spells of unemployment were avoided (Short-term crisis…, 2012).

According to the International Labour Organisation (2012), there is an extensive body of literature which demonstrates the central importance of qualifications on labour market outcomes. Young people with an education level below tertiary are more likely to be passed over by employers in favour of their more highly educated peers (Global Employment Trends…, 2012).

Geography can also play a part in the decisions young people make. The areas in which young people live can be damaging to their prospects of finding a job, especially if they are residing in neighbourhoods with many other unemployed people The consequences of this pertain to the lack of information about jobs as a result of social networks (Green et al., 2007).

According to Audas, Berde, Doliton (2005), there is a growing literature examining many aspects of economic reform and its effect on unemployment and the labour markets of European countries. Despite this, very little attention has been paid to the individuals who will be most affected by these reforms: young people.

In all European countries young people are acquiring more education and staying in full-time education longer. As a result, the length of the school-to-work transition is increasing in duration - imposing greater financial support burdens on the state and parents as well as inducing higher levels of indebtedness in young people. Studies that have been directed towards young people in transition economies have concentrated on access to secondary education and academic achievement. Other studies have examined the changing returns to education during the transition from planned to market economies. For instance, Newell and Reilly (1999) found evidence of increasing returns to education as economies became more market orientated. However, little is known about how young people move from secondary education to tertiary education or employment (Audas et al., 2005).

The author agrees with this assumption because nowadays there is a large part of students without work experience and that is the main reason why they have problems to find a job after their graduation. On the one hand, it is positive because they spend all their time on studies, but on the other hand, when they graduate from a university or college, they will not have a comparative advantage in the labour market.

Active discussions of long-term unemployment trends and issues in Latvia are made by economists and researchers such as Krasnopjorovs, Rasnaca and Hazans.

The author Hazans considers that a decrease of economic activity led to a rapid increase of labour force emigration. According to the calculations made by labour market experts, the net outflow of the Latvian population was as follows: 68 000 in 2004 – 2008 and 48 000-70 000 in 2009 – 2010. The highest figure might be treated as a more realistic estimation (Hazans, 2011). Estimations show that the share of young population (aged 18-24) among other groups of migrants has increased by 9.0 p.p. during 2009 – 2010, comparing with the period of 2004 – 2008 (Hazans, 2011).

It has increased dramatically in years of economic recession (up to 37.2% in 2010) and remains high in 2011 (at 31.0%). However, economists have pointed out that unemployment among young people is not higher than among other age groups (Krasnopjorovs, 2012). The high unemployment rate of young people is the result of calculation features, i.e., unemployment is calculated as a share of job-seekers in economically active population, and more than half of the Latvian population aged 15 – 24 is not economically active (due to studying etc.). According to Krasnopjorovs' calculations, if the share of economically active young population in Latvia is of the same size as in the Netherlands, Germany and Austria, the unemployment rate of them will not exceed 10% (Krasnopjorovs, 2012).

Skills mismatch on youth labour markets has become a persistent and growing trend. Over-education and over-skilling coexist with undereducation and under-skilling, and increasingly with skills obsolescence brought about by long-term unemployment. Such a mismatch makes solutions to the youth employment crisis more difficult to find and more time consuming to implement. Moreover, to the extent that young people in employment are actually overqualified for the job they are doing, society is losing their valuable skills and forfeiting stronger productivity growth that would have been achieved had these young people been employed at their appropriate level of qualification (Global Employment Trends…, 2013).

The author agrees that one of the main problems for youth long-term unemployment is the mismatch between youth skills and requirements of employers.

The authors Lee, Sissons, Balaram, Jones and Cominetti (2012) presented data about the occupations sought by young job seekers. They find that:

- Long-term youth unemployment has been rising both before and as a result of the recession;
- Young men are more likely to be unemployed than young women. This is even more the case amongst the long-term young unemployed;
- The long-term unemployed are significantly more likely to have low or no qualifications;
- A large proportion of both short and long-term young unemployed people express a preference for full-time working;
- Most unemployed young people seek jobs in sales and customer service, and elementary occupations (Short-term crisis…, 2012).

The requirements caused by today's economic and technological development promote the importance of skilled labour and provide a strong impetus to the intensification of social development. In this context, the youth unemployment is an undesirable phenomenon, which decreases the effectiveness of young people in the labour market by increasing social costs and limiting the development of society. The youth labour market position depends on a number of social, economic and demographic factors that lead to the conclusion that youth unemployment as a social and economic phenomenon is a particularly negative outcome of interaction between these factors.

According to the Lisbon Strategy for Growth and Jobs and the European Youth Pact, promoting labour market access and quality of employment has been a key priority. The impact of the financial and economic crisis on labour markets adds urgency to addressing youth employment for both the short- and long-term. The free movement of labour, especially relevant for young people at the start of their careers, is a cornerstone of the Single Market (Communication from the…, 2009).

In standard Unemployment Search Theory, unemployment that is a consequence of an inappropriate match between the employer and employee will have a positive effect on subsequent wages. Durations of unemployment are used for job search and thus improve the likelihood of a good employer-employee match in subsequent jobs. However, Pissarides (1994) extends these models to include on-the-job search and here, with dispersion in firm productivity, low quality firms recruit the unemployed but lose them to better paying higher productivity firms. Displacement from a good job means a high probability of return to a lower quality one and hence a cost-of-job loss. Part of these costs will be permanent if the worker remains in the low wage sector to retain firm specific human capital which would be lost on a switch to a better paying firm (Short-term crisis…, 2012).

The author thinks that the main problem of youth long-term unemployment is incommensurable requirements of employers for young people. It will be clear if employers give the opportunity for young people to acquire the necessary skills for the vacancy and to prove themselves.

The current youth long-term unemployment situation. According to the International Labour

Organization (2013), the weakening of the global recovery in 2012 and 2013 has further aggravated the youth jobs crisis and the queues for available jobs have become longer and longer for some unfortunate young job seekers. So long, in fact, that many youth are giving up on the job search and choose to study only. The prolonged jobs crisis also forces the current generation of youth to be less selective about the type of job they are prepared to accept, - a tendency that was already evident before the crisis. Increasing numbers of youth are now turning to available part-time jobs or find themselves stuck in temporary employment. Secure jobs, which were once the norm for previous generations – at least in the advanced economies – have become less easily accessible for today's youth (Global Employment Trends…, 2013).

The rise in the number of 16-24 year olds unemployed for 12 months or more predates the recent economic downturn. Between 2005 and 2007 youth long-term unemployment rose from 59,000 to around 114,000. However, the recession has exacerbated the problem – since the 2008 recession hit, long-term youth unemployment has more than doubled, rising to 264,000. Indeed, the rate of long-term youth unemployment has risen faster than overall youth unemployment during the recession (Short-term crisis…, 2012).

The global youth unemployment rate, estimated at 12.6% in 2013, is close to its crisis peak. As many as 73 million young people are estimated to be unemployed in 2013. At the same time, informal employment among young people remains pervasive and transitions to decent work are slow and difficult. The economic and social costs of unemployment, long-term unemployment, discouragement and widespread low-quality jobs for young people continue to rise and undermine economies' growth potential (Global Employment Trends…, 2013).

According to the diagram, the author could see that unemployment increased equally among the Baltic States until 2009 and started to decrease in 2011. A higher youth long-term unemployment figure was in Latvia in 2009, when youth long-term unemployment reached more than 70 thousand (in the beginning of 2012 in Latvia lived approximately 2.2 million inhabitants). But in Lithuania youth long-term unemployment reached the highest rate in 2010 when it was 82 thousand (in the beginning of 2013 in Lithuania lived 2.98 million inhabitants) (Figure 1).

Unemployment while young can lead to long-term reductions in wages, increased chances of subsequent periods of unemployment, and poorer health outcomes. High levels of youth long-term unemployment also have wider social and economic costs (Short-term crisis…, 2012). The author agrees to the above statement and also considers that so high youth long-term unemployment is representing a serious economic and social challenge.

In Latvia, education has a greater impact on a person's chances to be employed rather than the age group (Figure 2). In 2010, unemployment among youth who were not in education and training was 25.7%, while among youth who were more than 12 months without work – 18.9%. It seems that most of the youths who are long-term unemployed are not in education and training. Also in 2010 the youth long-term unemployment was high – 18.4%, and youth who were not in education – 23.3%.

These indicators are too high and they declined insufficiently, which mainly refers to the fact that

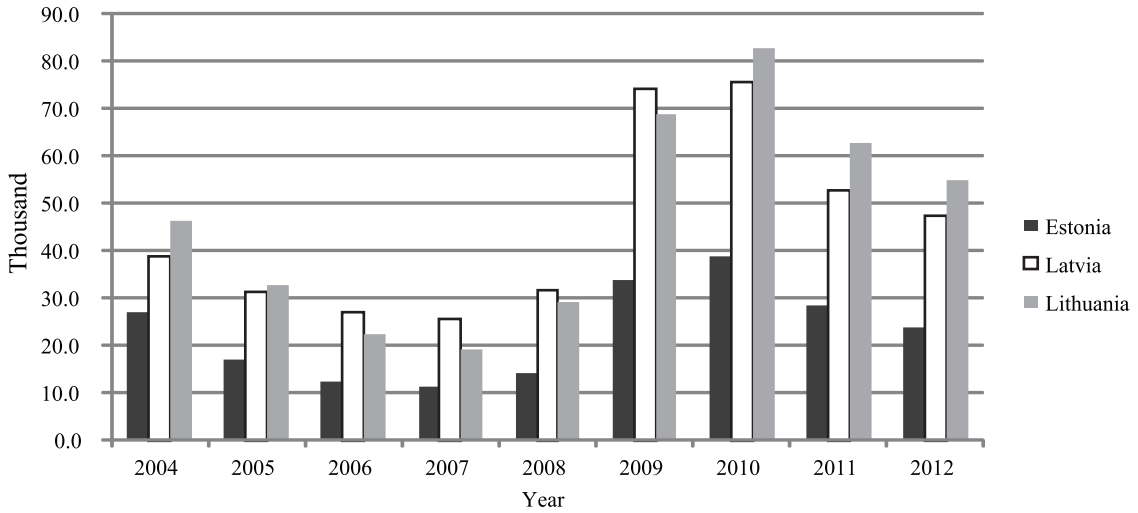


Figure 1. Youth long-term unemployment dynamics in the Baltic States for the 15 - 29 year olds from 2004 to 2012 (thousand).

Source: author's construction based on Eurostat data, 2013.

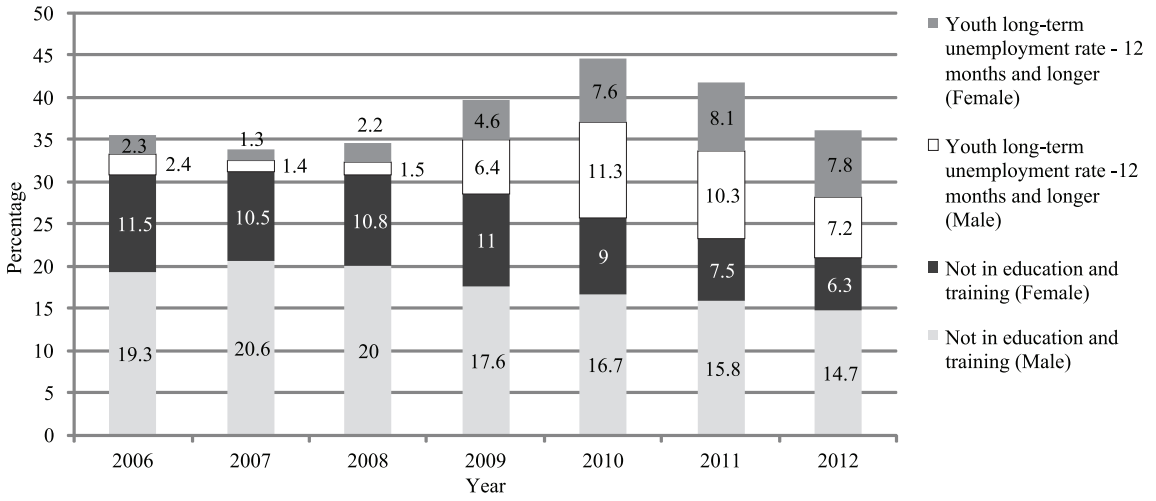


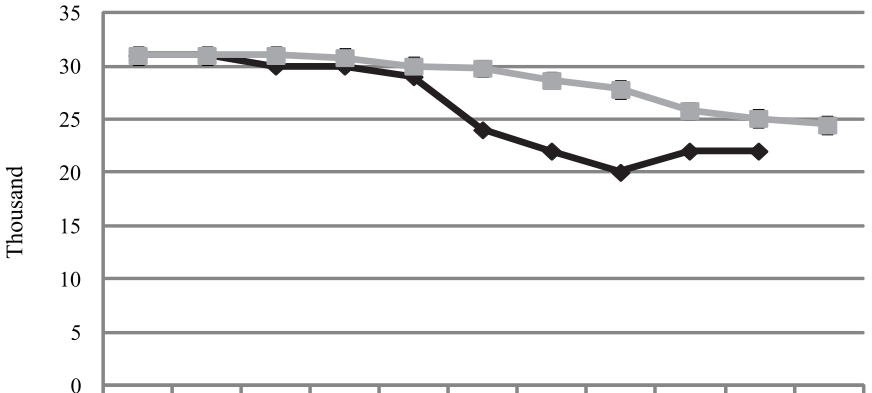
Figure 2. Dynamics of the youth long-term unemployment rate (12 months or longer) by gender and age, and youth not in education and training from 2006 to 2012 in Latvia (%).

Source: author's construction based on the data of Central Statistical Bureau of Latvia, 2013.

the government has not paid enough attention to this problem.

According to author Zabko (2012), the high rate of young people not in employment, not in education and training (NEET) becomes a crucial issue. The NEET rate among other European countries indicates that Latvian policy makers are particularly interested in programmes that facilitate the transition of poorly performing students and low-skilled young people into the labour market. The NEET rate increased less than the unemployment rate of young people, and it might be assumed that some dismissed young people have been engaged in the active labour market policy measures. The author believes that this is a positive aspect because inactive young people are being involved in various activities that will contribute to youth's future prospects to find a job (Zabko, 2012).

Based on the time series analysis, the author calculated a forecast of the youth unemployment rate for the 1st quarter of 2014, which was 24.45 thousand. Figure 3 shows that a higher youth unemployment rate was in the 3rd and 4th quarters of 2011. According to the author's calculations, the average mean absolute deviation (MAD) is 2.994 if N=3.



	2011 Q3	2011 Q4	2012 Q1	2012 Q2	2012 Q3	2012 Q4	2013 Q1	2013 Q2	2013 Q3	2013 Q4	2014 Q1
Statistical data of unemployment (Less than 25 Years)	31	31	30	30	29	24	22	20	22	22	
Forecast of unemployment (Less than 25 Years)	31	31	31	30.8	30	29.8	28.64	27.8	25.82	25.08	24.45

Figure 3. Forecast of the youth unemployment rate (less than 25 year olds) from 3rd quarter 2011 to 1st quarter 2014 in Latvia (thousands).

Source: author's calculations based on Eurostat data, 2013.

Based on the analysis and statistical data, the author considers that there is a positive trend, as the youth unemployment has decreased since the 1st quarter of 2013, and the forecast shows that there will be a positive impact on the future. The author thinks that it is explicable by youth employment projects that are financed by the European Union and implemented by the State Employment Agency of Latvia.

According to Barslund and Gros, the European Social Fund will provide funding (starting from early 2014) for youth access to employment, education or high-quality traineeships within four months (the Youth Guarantee). The details of implementation, which will naturally vary from country to country, are unclear (Barslund et al., 2013).

Conclusions

The author considers that the global youth long-term unemployment problem is one of the main tasks to be tackled at the European level because the youth's future depends on the financial volume of employment support programmes, the price of higher education, the number of free state-financed study places, the financial volume of self-employment support programmes, employers' flexibility/their ability to adjust, and changes in the legislation for the prevention of long-term unemployment.

The transition periods of young people from education to employment have become significantly longer and complex than a few years ago. It is hard to find an adequate job which corresponds to their qualifications.

In the labour market for young people, it is more likely to find some low-skilled job with less pay than work that is appropriate to their education.

Globalisation and the effect of the current economic situation put further pressure on the labour market opportunities for the young people. Promoting the labour market access and the quality of employment needs to be the key priority of Latvia's government.

Nowadays technologies offer new opportunities for learning and participating in different events. The encouraging of entrepreneurship and the innovation of government will make more interest of young people in self-employment, participation in business support programmes, business' financial side and will provide a return link.

To solve the long-term youth unemployment problem, economic and employment growth is a core need. Government policies must focus on growth in the labour market.

References

1. Arumlampalam W. (2001) Is unemployment really scarring? Effects of unemployment experiences on wages, *The Economic Journal,* Vol. 111, No. 475, pp. 585 – 606.
2. Audas R., Berde E., Doliton P. (2005) Youth Unemployment and labour market transitions in Hungary, UK: London, Routledge, *Education Economics*, No. 13, Vol. 1, pp. 1 – 25.
3. Barslund M., Gros D. (2013) Unemployment is the scourge, not youth unemployment per se. The misguided preoccupation with youth. Brussels: *Centre for European Policy Studies.* No. 294. pp. 1 – 10.
4. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions (2013) Youth employment Initiative. *European Commission.* Strasbourg. pp. 1 – 4.
5. Goša Z. (2003) Statistika (Statistics). *Latvijas Universitāte,* SIA Izglītības soļi, 245 – 292. lpp. (in Latvian).
6. Green A.E., White R.J. (2007) Attachment to place: Social networks, mobility and prospects of young people, *Warwick University, Joseph Rowntree Foundation,* pp. 1 – 107.
7. Gregg P., Tominey E. (2005) The Wage Scar from Youth Unemployment, Labour Economics, UK: Bristol, *Department of Economics,* pp. 487 – 509.
8. Global Employment Trends for Youth 2012 (2012) International Labour Organisation, Geneva: ILO. Available at: http://www.ilo.org/wcmsp5/groups/public/---dgreports/---dcomm/documents/publication/wcms_180976.pdf, 13 February 2014.
9. Global Employment Trends for Youth 2013. A Generation at risk (2012) International Labour Organisation, Geneva: ILO. Available at: http://www.ilo.org/wcmsp5/groups/public/---dgreports/---dcomm/documents/publication/wcms_212423.pdf, 13 February 2014.
10. Hazans M. (2011) The changing face of Latvian emigration, Human Development Report 2010/2011. National Identity, mobility and Capability. Riga: *Advanced Social and Political Research Institute of the University of Latvia,* pp. 77 – 101.
11. Jobs and Enterprise in Deprived Areas (2004) Social Exclusion Unit, London: Office of the deputy Prime Minister. Available at: http://simonpoulter.co.uk/iod/iodpdf/JobsEntfinalreport.pdf, 6 February 2014.
12. Krasnopjorovs O. (2012) Jauniešu bezdarbs Latvijā un Eiropā: reāla problēma vai skaitļu dancis? (Youth Long-term Unemployment in Latvia: the Real Problem or a Dance of Numbers?). Available at: http://www.makroekonomika.lv/category/tags/bezdarbs?page=1, 28 February 2014. (in Latvian).

13. Lee N., Sissons P., Balarm B., Jones K., Cominetti N. (2012) Short-term Crisis – long-term Problem? Addressing the Youth employment challenge. *The Work Foundation, Part of Lanchester University,* pp. 1 – 50.
14. Mācības pārtraukušie jaunieši 18-24 gadu vecumā pilsētās un laukos pēc dzimuma (Early leavers from education and training aged 18-24 in urban and rural areas by sex) (2014) *Centrālā Statistikas pārvalde.* Available at: http://data.csb.gov.lv/Menu.aspx?selection=Sociala__Ikgadējie%20statistikas%20dati__Nodarbinātība&tablelist=true&px_language=lv&px_type=PX&px_db=Sociala&rxid=cdcb978c-22b0-416a-aacc-aa650d3e2ce0, 6 February 2014. (in Latvian).
15. Unemployment of young people still a major issue in Latvia (2013) Available at: http://www.csb.gov.lv/en/notikumi/unemployment-young-people-still-major-issue-latvia-39293.html, 6 February 2014.
16. Youth self-employment by sex, age and educational attainment level (2014) Eurostat. Available at: http://epp.eurostat.ec.europa.eu/portal/page/portal/employment_unemployment_lfs/data/main_tables, 6 February 2014.
17. Youth long-term unemployment rate (12 months or longer) Eurostat (2014) Available at: http://epp.eurostat.ec.europa.eu/portal/page/portal/employment_unemployment_lfs/data/main_tables, 12 February 2014.
18. Youth unemployment by sex, age and educational attainment level (From 15 to 29 years) Eurostat (2014) Available at: http://epp.eurostat.ec.europa.eu/portal/page/portal/employment_unemployment_lfs/data/main_tables, 12 February 2014.
19. Zabko O. (2012) Latvia at the Cross-roads of Vocational Training Reform-Chances to introduce the Dual Training System. *Mutual Learning Programme: Peer Country Comments Paper- Latvia.* Autumn Peer Reviews. pp. 1 – 10.

PROJECT ACTIVITIES AS TOOL FOR THE PLACE IMAGE FORMATION: CASE STUDY OF LITHUANIAN DISTRICT SILALE

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Abstract
The positive place image attracts investors, foreign and national guests, creates the local residents' pride and distinguishes it form the competing locations. Project activities are completed/or being carried out under the funding of the European Union and the Republic of Lithuania. The research problem: do project activities form positive place image? The research object – place image formation carrying out project activities. The purpose of the article – to analyze the implemented projects by Silale district Municipality and investigate their impact on the location image formation in Silale district. Research objectives are (1) to identify and investigate the factors impacting the formation of Silale district Image and (2) to analyze and assess the project activities performed by Silale district Municipality. For the research completion the methods of questionnaire survey and content analysis were applied. The gained research outcome has disclosed that project activities in Silale district are focused to the restoration and beautifying of environment, but not on the investors, and there are not carried out any investment attraction projects. Two segments – local residents and tourists – received the benefit from the project activities in Silale district.
Key words: place image, project, Silale district.

Introduction

The place image formation is analyzed in the place marketing concept. Ch. Henry and J. F. Peters (2010) describe *image* as the perception of environment, i.e. how people perceive and comprehend environment. Ch. Henry and J. F. Peters (2010) state that image is human sensations that are evoked by object colors, shapes and sizes, present in the certain place.

H. S. Martin and I. A. R. Bosque (2008), describe the place image as the expression of the possessed knowledge, impressions, superstitious beliefs, imagination and emotions related to the human's view formed about a certain place. According to G. McCartney et al., (2008) – image is a model expressing the individual's beliefs and comprehension about phenomena and situations. Ph. Kotler and Ch. Asplund et al. (1999) define the place image as the whole of associations, expectations, thoughts and impressions related to the place. Places have to consider different ways, under which they could create their image due to their unique conditions or possibilities. In order to maintain and foster the attractiveness to compete with other places, first, it is necessary to know what kind of image they would like to have. According to Ph. Kotler and Ch. Asplund et al. (1999), image might be too attractive, positive, weak, contradictory or negative.

Assessing the place image under the tourism aspect, according to K. K. Byon and J. J. Zhang (2009), there are identified three image types: organic, excited and complex. The following three image types originate from individuals' experience about a certain travel destination. Organic image originates from non-tourism information sources – geography textbooks, TV commentaries or newspaper articles. Excited image might originate from specific tourism information sources – travel brochures, holiday websites, i.e. due to tourism marketing efforts. K. K. Byon and J. J. Zhang (2009) state that the greatest difference between organic and excited image is individuals' travel aims and motivation, i.e. every individual might have an organic image of the certain place even though an individual does not have any certain travel aims/destinations. Complex image manifests as a result of the direct experience about the certain place. K. K. Byon and J. J. Zhang (2009) distinguish nine cognition factors concerning the travel place image: developed environment, natural environment, value, excursion possibilities, risk, novelty, climate, comfort and family status.

K. K. Byon and J. J. Zhang (2009) add eight dimensions to the cognition factors of the place image: leisure time and tourism convenience; selection of shopping and food; local residents and night life; political stability of *place*; risk, adventure and climate; culture; tendency; personal safety and comfort.

Although the cognition factors of the place image by K. K. Byon and J. J. Zhang (2009) are underlying for the certain tourists' segment; however, the majority of these factors are general – topical for other *place* participants as well. H. Easthope (2009) agrees with K. K. Byon, J. J. Zhang (2009) and also distinguishes the physical place environment as single, most significant key element that contributes to the place *interpretation*.

Similar five place image aspects are distinguished by A. A. Aksu et al., (2009), exactly in the case of Antalya region in Turkey: shopping; health and hygiene conditions; information; transport and accommodation. The following place image cognition factors distinguished by A. A. Aksu et al., (2009), although they were formulated for the certain tourists'

segment analysis, are relevant and applicable for other place participants.

The place image formation is a purposeful activity that includes territories, regardless of whether it is a city, settlement, country, region or even interstate structure, advantage formation through people, culture and heritage, business, tourism, migration of workforce and policy with a view to the socio-economic development – the creation of the territory that is attractive for living, business and tourism.

Silale District Municipality is one of the place image formation participants. The image formation object includes project activities in Silale District Municipality. Project activities – the projects being completed or/and already completed under the funding of the European Union and the Republic of Lithuania. In the scientific project management literature according to H. Kerzner (2013), J. Ramanauskiene (2010), E. S. Andersen (2008), S. Lenfle and C. Loch (2008), R. Wysocky and R. McGary (2003) there are present different project classifications. Some projects are classified according to the defined aims and ways to reach them (engineering projects; product (service) creation projects; system creation projects; research and organizational reform projects). Other projects might be classified according to the solved problems, their topicality and the novelty of solutions (typical and unique projects). Some might be classified according to the field of activities (training and educational; research and development; innovation; investment). There are projects which are classified according to the duration: short-term (less than 3 years); average duration (3-5 years); long-term (more than 5 years).

The research problem: do project activities form positive place image? The research object – place image formation carrying out project activities.

Materials and Methods

The project activities are assessed under the method of Content analysis, i.e. documentation analysis of the projects completed by Silale district Municipality. The research was completed in January of the year 2014 in the department of Investments and Construction of Silale district Municipality. Research period was 2007 – 2013. During the following period the project activities were divided into 2 stages: the projects (32) completed to be performed in 2007 – 2013 and 30 projects are being completed (not completed yet) in 2007 – 2014.

The place image is assessed following 2 stages. First, there is selected the target audience – Silale district residents: the sample of 384. Second, it is measured how Silale district residents comprehend and assess the place qualities following the quantitative questionnaire survey method. The research was completed in January, 2014.

The administrative centre of Silale district Municipality is Silale city that is at a distance of 239 km from Vilnius, 144 km from Kaunas and 81 km from Klaipeda. Silale is at a distance of 31 km from the county centre – Taurage city. In Silale district Municipality there is present 1 city, 7 towns and 435 villages. According to the data of Statistics Lithuania, at the beginning of the year 2011, in Silale district Municipality there lived 28708 residents, 5827 of them resided in the city (i.e. 20 percent). The majority (80 percent) of municipality residents resided in the village.

Results and Discussion

The concept of place image formation. Measurement criteria of the place image and elicited versatile factors influence the comprehension of the place image formation. Due to the fact that places are different and vary in the distinctive advantages, it is difficult to determine identical factors for all places and it is quite complicated as there does not exist a unified system assessing all places. Due to the following reasons it is purposeful to select appropriate factors for certain places.

Most frequently highlighted factors of the place image formation – people, culture and heritage, business, tourism, migration of workforce and policy – involve different location segments: local residents, tourists and investors, - those are shown in Figure 1.

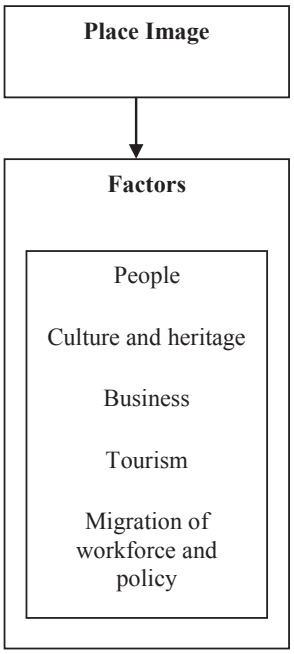

Figure 1. The factors impacting the formation of place image.

The place image formation is a purposeful activity that includes territories, regardless of whether it is

a city, settlement, country, region or even interstate structure, advantage formation through people, culture and heritage, business, tourism, migration of workforce and policy with a view on the socio-economic development – the creation of the territory that is attractive for living, business and tourism.

Project activities in Silale District Municipality. According to the significance of the project content in Silale district Municipality, there dominate technological, social and complex projects. According to the project novelty level, in Silale district Municipality both radical and modifying projects prevail. There is an example of a radical project: introduction of Parsezeris recreation zone, and of a modifying one – renewal of administrative premises. Carrying out projects under the innovation pattern, they are of high quality in Silale district Municipality in order to improve management, residents' service and personnel welfare. To high quality projects there might be added ones that contribute to the new activities for the renewal of disused buildings, creation of new conditions for the running of business in the place, where there was no possibility of doing it. Such high quality projects improve the district image. Silale District Municipality manages its own budget, and as a result, it chooses projects for the execution based on its employees' point of view and under the resolution approval by the Board members. In Silale District Municipality there are totally completed 32 projects up to the year 2013, and there are being completed 32 projects from 2007 to 2014. The executed project might be classified according to the extent point, these are onetime projects. Projects under the impact areas: economic – 16, social – 10, ecological – 3 and complexes – 3. According to the location level: settlements – 15, Silale town – 10, Lithuania – 7. The value of the implemented projects is 6.6 mln Lt., and ongoing projects is 23 mln Lt.

Assessment of Silale District as the location image according to tourism, culture and heritage, business, infrastructure, workforce migration and policy. Reliability of questionnaire questions. *Cronbach's alpha* coefficient that is based on separate questions, those complete the questionnaire, correlation and assessed if all scale questions reflect the researched measurement sufficiently and enables the specification of the requested questions in the scale. Consequently, to assess the variable reliability in questions related to tourism, culture and heritage, business, workforce migration and policy, Cronbach's alfa coefficient was selected as shown in Table 1.

All coefficients exceed 0.8, and as a result a conclusion might be drawn that the questions are consequential and reliable. The highest reliability manifests in the assessment of the following category questions: culture and heritage field in Silale district (0.918) and business development possibilities in Silale district (0.892).

Factoring analysis. During the factoring analysis, the tourism image possibilities in Silale district were defined after having found out the coefficient of Kaise-Meyer-Olkin as shown in Figure 2.

Due to the fact that the coefficient of Kaise-Meyer-Olkin is 0.894 and sig. = 0.000, the statements can be distributed into separate factors, as it is significant in a static way. Three positive factors that form the place

Table 1

Cronbach's alfa coefficients for blocks of questions

Blocks of questions	Number of questions completing the block	Cronbach's alpha α
1. Tourism development and possibilities in Silale District	13	0.848
2. Assessment of the culture and heritage field in Silale District	6	0.918
3. Business development possibilities in Silale District	9	0.892
4. Assessment of infrastructure in Silale District	8	0.879
5. Assessment of investment opportunities	9	0.828
6. Assessment of the situation improvement in Silale District during the last 5 years according to separate fields	9	0.833

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		,894
Bartlett's Test of Sphericity	Approx. Chi-Square	1561,245
	df	78
	Sig.	,000

Figure 2. Kaise-Meyer-Olkin coefficient - tourism of Silale District.

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		,830
Bartlett's Test of Sphericity	Approx. Chi-Square	867,294
	df	15
	Sig.	,000

Figure 3. Coefficient of Kaise-Meyer-Olkin concerning the culture and heritage in Silale District.

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		,886
Bartlett's Test of Sphericity	Approx. Chi-Square	894,395
	df	36
	Sig.	,000

Figure 4. The coefficient of Kaise-Meyer-Olkin for business in Silale District.

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		,869
Bartlett's Test of Sphericity	Approx. Chi-Square	1267,175
	df	45
	Sig.	,000

Figure 5. The coefficient of Kaise-Meyer-Olkin for infrastructure in Silale District.

image were elicited for tourism development and possibilities in Silale district:

1. It is an original location for the development of tourism – there are unusual places of sightseeing;
2. There are enough authentic Lithuanian shopping places and enough hotels;
3. Friendly local residents and a safe district.

Assessment of Silale district as the place image according to culture and heritage. During the factoring analysis the question block on the image concerning the culture and heritage in Silale district was checked. And the coefficient meaning of Kaise-Meyer-Olkin was found as shown in Figure 3.

The coefficient meaning of Kaise-Meyer-Olkin is 0.830, and sigma is equal 0.000. That shows that the separation of factors is significant in a static way. In the following block of questions one factor is separated that forms a positive image concerning the culture and heritage in Silale district, i.e. 'In Silale district there is always something for outgoing: a variety of concerts, festivals and events'.

Assessment of Silale district as the place image according to business. During the factoring analysis the reliability of the question block related to Image concerning the business in Silale district was checked and the coefficient meaning of Kaise-Meyer-Olkin was found out as shown in Figure 4.

The coefficient meaning of Kaise-Meyer-Olkin is 0.886, and sigma is equal 0.000. That shows that the separation of factors is significant in a static way. In the following block of questions there two factors were elicited that form a positive image concerning the business in Silale district:

1. In the field of Logistics and Transport;
2. In the field of Information Technologies (IT).

Assessment of Silale district as the place image according to infrastructure. During the factoring analysis the block of questions on the place image related to infrastructure in Silale district were checked and the coefficient meaning of Kaise-Meyer-Olkin was found out as shown in Figure 5.

Due to the fact that the coefficient of Kaise-Meyer-Olkin is 0.869, and sig. = 0.000, the statements about infrastructure can be distributed into the separate factors as it is significant in a static way. Two positive infrastructure factors that form the place image were elicited:

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		,870
Bartlett's Test of Sphericity	Approx. Chi-Square	918,368
	df	28
	Sig.	,000

Figure 6. Kaise-Meyer-Olkin koeficientas for workforce, migration and policy in Silale District.

1. Developed places and interregional commutation,
2. Tidy streets and there are present car-parking lots.

Outcomes of Silale district as the place image according to workforce, migration and policy. In the following block of questions, the respondents had to assess the improvement of situation in Silale district during the last 5 years according to different fields: tourism, infrastructure, higher education, culture and heritage, immigration, export, farming, environmental protection (waste assortment and responsibility for environment). During the factoring analysis, the place image on workforce, migration and policy during the last 5 years in Silale district was determined. The determined coefficient of Kaise-Meyer-Olkin is as shown in Figure 6.

Due to the fact that the coefficient of Kaise-Meyer-Olkin is significant in a static way, during the factoring analysis two positive factors were elicited: 1. Tourism and 2. Infrastructure. That shows the District improvement in tourism and infrastructure areas over the past 5 years in Silale district.

Summarizing the outcomes of the factoring analysis, it should be noted that all elicited factors form a positive image in Silale district. In order to attract greater visitor flows to Silale district, it is worth invoking the measures that foster the cognitive tourism as, based on the questionnaire survey outcomes, it is a favorable place to develop tourism in Silale district. Picturesque landscape, Lithuanian dish catering establishments, and authentic shopping points that make favorable conditions for the development of tourism reflect the following: the development of tourism and its expansion possibilities in Silale district. Having implemented all projects planned for 2007 – 2013, the tourism attractiveness of Silale district and application efficiency of energy resources improved, and there was seen the reduction of negative impact on environment. Ecological condition and landscape also have improved.

Culture and heritage distinction in Silale district is reflected under the factor, defined during the questionnaire survey: 'In Silale district there is always something for outgoing: a variety of concerts, festivals and events'. It is recommended to present the distinction and uniqueness of culture and heritage in different fairs and events, to expand the spectrum of cultural events, to organize more intercity events that will attract local tourists from the largest Lithuanian cities. Having carried out the questionnaire survey research, it was indicated that the residents see the greatest business development possibilities in the fields of information technologies (IT) and logistics. Business is a significant source of employment, creation of new workplaces and attraction of investment, and due to these reasons, businesses are one of the best ways, contributing to the increase of general living standard and economic welfare in Silale district.

As the empiric research outcomes have disclosed, infrastructure in Silale district is mostly connected to the developed places and interregional commutation and tidy streets and there are present car-parking lots. Having implemented all projects, planned for 2007 – 2013, the tourism attractiveness of Silale district and application efficiency of energy resources improved, and there was seen the reduction of negative impact on environment. Ecological condition and landscape also have improved. In this case, the project benefits reached the residents and visitors of Silale district.

Having carried out the analysis of project activities and the place image formation factors, it can be stated that completed and still ongoing project activities in Silale district Municipality form a positive image for local residents and tourists.

Conclusions

1. The place image is connected to the possessed and stored knowledge about the certain place and emotions evoked by the particular place. Different factors impacting the comprehension of the place image formation were identified. Due to the fact that locations are different and vary in advantages, it is quite complicated to determine identical factors for all places as there is not present any unique distinct system for the assessment of all locations. Due to the following reasons, it is purposeful to select relevant factors for certain places. The most frequently highlighted factors of the place image formation are as follows – people,

culture and heritage, business, tourism, workforce migration and policy – involving different place segments: residents, tourists and investors.

2. The results showed the factors impacting the formation of positive image in Silale District are as follows: one factor as 'in Silale district there is always something for outgoing: a variety of concerts, festivals and events' forms a positive image concerning the culture and heritage. Two factors as: (1) in the field of Logistics and Transport and (2) in the field of Information Technologies (IT) - form positive image concerning the business. Three positive factors that form the place image were elicited for tourism development and possibilities: (1) it is an original location for the development of tourism – there are unusual places of sightseeing, (2) there are enough authentic Lithuanian shopping places and enough hotels and (3) friendly local residents and a safe district. Migration of workforce and policy form two positive factors: (1) tourism and (2) infrastructure. That shows the District improvement in tourism and infrastructure areas over the past 5 years in Silale district.
3. Results from data analysis showed that in Silale district Municipality there are totally completed 32 projects up to the year 2013. The executed projects might be classified according to the extent point, - these are onetime projects. Projects under the impact areas: economic – 16, social – 10, ecological – 3 and complex – 3. According to the location level: settlements – 15, Silale town – 10, Lithuania – 7. The value of the implemented projects is 6.6 mln Lt., and ongoing projects is 23 mln Lt. Project activities are focused on the restoration and beautifying of environment, but not on the investors, and there are not carried out any investment attraction projects. The benefit from the project activities in Silale district reached two segments: local residents and tourists.
4. The advantages of the projects implemented for the district image in Silale are as follows: the spare time and activities for the district residents increased, the image of Silale district improved, and the efficiency of energy resource application and service provision secured. Also, increased attractiveness of camping places and tourism attractiveness in the whole Silale district.

References

1. Aksu A.A., Caber M., Albayrak T. (2009) Measurement of the destination evaluation supporting factors and their effects on behavioral intention of visitors: Antalya region of Turkey. *Tourism Analysis*, Vol. 14, 116 p.
2. Andersen E.S. (2008) *Rethinking project management: an organizational perspective*. England: Prentice Hall, pp. 5, 10, 49.
3. Byon K.K., Zhang J.J. (2009) Development of scale measuring destination image. *Marketing Intelligence & Planning.* Vol. 28, No. 4, pp. 510 – 512.
4. Easthope H. (2009) Fixed Identities in a Mobile World? The Relationship Between Mobility, Place, and Identity. *Identities: Global Studies in Culture and Power*, Vol. 16, No.1, pp. 61 – 82.
5. Henry Ch., Peters J.F. (2010) Perception – based image classification. *International Journal of Intelligent Computing and Cybernetics*, Vol. 3, No. 3, pp. 411 – 413.
6. Kotler Ph., Asplund Ch., Rein I., Haider D.H. (1999) *Marketing places Europe*. London: Prentice Hall, pp. 160 – 162.
7. Kerzner H. (2013) *Project management: a systems approach to planning, scheduling and controlling*. New Jersey: Johan Wiley and Sons, pp. 21 – 23.
8. Lenfle S., Loch C. (2008) Lost roots: how project management came to emphasize control over flexibility and novelty. *California management review,* No. 53, pp. 32 – 55.
9. Martin H.S., Bosque I.A.R. (2008) Exploring the cognitive-affective nature of destination image and the role of psychological factors in its formation. *Tourism Management.* Vol. 29, pp. 263 – 277.
10. McCartney G., Butler R., Bennett M. (2008) Positive tourism image perceptions attract travelers – fact or fiction? The case of Beijing visitors to Macao. *Journal of Vacation Marketing*, Vol. 15, No. 2, pp. 179 – 193.
11. Ramanauskiene J. (2010) *Innovation and Project Management.* Kaunas: LŽŪU, pp. 31 – 45.
12. Wysocky R., McGary R. (2003) *Effective project management*. Indiana: Wiley Publishing, Inc., 13 p.

RURAL TOURIST SATISFACTION INDEX: A CASE OF LITHUANIA

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Abstract
Tourism industry is becoming one of the fastest growing industries in the world. Considering its significance in the economy of many countries, the research in tourism is growing, as well. Achieving to develop tourism industry, tourist satisfaction becomes a considerable goal for many countries. In this article, rural tourism is taken into consideration. However, scientific research in the field of Lithuanian rural tourist satisfaction is still scarce. Therefore, the level of Lithuanian rural tourist satisfaction and the factors determining their satisfaction are being determined in current research aiming to elaborate Rural Tourist Satisfaction Index in Lithuanian framework. Research results highlighted that the determinants of Lithuanian rural tourist satisfaction are: 'accommodation and catering', 'destination aesthetics', 'environmental preservation', 'destination marketing' and 'perceived value'. Rural tourists in Lithuania value the benefits of 'green marketing', amenities and the efforts of expanding the variety of activities; the emphasis of all these aspects is perceived as 'destination marketing'. On the other hand, levels of activities in rural destinations, quality of accommodation and catering, and aesthetics in Lithuanian rural destinations are insufficient. Enhancing these aspects could result in higher satisfaction and loyalty levels of rural tourists, and that would contribute to the rural tourism development in Lithuania.
Key words: rural tourism, structural equation modelling, satisfaction index.

Introduction

Tourism industry is a fast growing industry and it becomes an increasingly important sector (Lalromawia and Ramana, 2013). In many countries, a growing tourism industry is seen as a potential solution to issues such as low employment rates or the need for foreign currencies and generating higher government revenues (Rid et al., 2014). Considering that rural tourism incorporates two forms of tourism – local and inbound (Žalys et al., 2006), it makes a significant contribution to the rural economy and to the wider tourism industry (Haven-Tang and Jones, 2012). Moreover, rural tourism can be considered as a sustainable activity and serves as a basis for sustainable and renewable energy promotion (Baležentis et al., 2012). Consequently, rural tourism development is an important issue for many countries, including Lithuania.

According to Selladurai and Sundararajan (2013), in order to develop tourism industry, tourist satisfaction has been a considerable goal for many countries. Several scholars note that tourist satisfaction is a crucial factor to generate destination loyalty (Shirazi and Mat Som, 2013). Bearing in mind that rural tourism can be regarded as a certain type of tourism, rural tourist satisfaction becomes an important factor in order to develop rural tourism industry. Therefore, the scientific problem solved in the article rises with the question: what is Lithuanian rural tourist satisfaction level and what are the factors determining their satisfaction?

The object of the research is rural tourist satisfaction and the aim of the research is to elaborate Rural Tourist Satisfaction Index in Lithuanian framework.

Materials and Methods

Previously elaborated (Pilelienė and Grigaliūnaitė, 2014) Lithuanian tourist satisfaction index model was used as a basis for the research. Latter model contains six exogenous ('accommodation and catering', 'activities in destination', 'natural features', 'destination aesthetics', 'environmental preservation', 'destination marketing') and two endogenous ('satisfaction', 'loyalty') latent variables; all exogenous variables directly affect tourists' 'satisfaction', as well as 'loyalty'. Considering the fact that most of the Customer Satisfaction Index models contain variable 'perceived value', which statistically significantly affects 'satisfaction' (see Grigaliūnaitė and Pilelienė, 2013; Pilelienė and Grigaliūnaitė, 2013), the assumption was made that variable 'perceived value' may possibly affect tourists' 'satisfaction'. Consequently, 'perceived value' was included in the theoretical Rural Tourist Satisfaction Index model. Since destination marketing, branding, and image are formed by many factors: leisure, recreation, infrastructure, environment, amenities and etc. (Chang, 2009; Hassan et al., 2010), the assumption was made that 'destination marketing' might be not an exogenous, but endogenous variable, influenced by all of the remaining exogenous variables in the model. Consequently, structural equations representing the elaborated theoretical Rural Tourist Satisfaction Index model are (1-4):

(1) Destination marketing = β_{60} + β_{61} Accommodation and catering + β_{62} Activities in destination + β_{63} Natural features + β_{64} Destination aesthetics + β_{65} Environmental preservation + ζ_6;

(2) Perceived value = β_{70} + β_{71} Accommodation and catering + β_{72} Activities in destination

+ β_{73} Natural features + β_{74} Destination aesthetics + β_{75} Environmental preservation + β_{76} Destination marketing + ζ_7;

(3) Satisfaction = β_{80} + β_{81} Accommodation and catering + β_{82} Activities in destination + β_{83} Natural features + β_{84} Destination aesthetics + β_{85} Environmental preservation + β_{86} Destination marketing + β_{87} Perceived value + ζ_8;

(4) Loyalty = β_{90} + β_{91} Accommodation and catering + β_{92} Activities in destination + β_{93} Natural features + β_{94} Destination aesthetics + β_{95} Environmental preservation + β_{96} Destination marketing + β_{97} Perceived value +β_{98}Satisfaction + ζ_9.

Considering that when manifest variables are manifestations of the construct (not the defining characteristics of it), changes in the construct do cause changes in the indicators, indicators share a common theme, dropping an indicator does not alter the conceptual domain of the construct, and indicators covariate with each other, indicators should be regarded as reflective ones (Petter et al., 2007), the chosen measurement model is reflective. The theoretical Rural Tourist Satisfaction Index model has 22 manifest variables, adapted to the specifications of rural tourism. Accordingly, 22 manifest variables formed a questionnaire for respondents' evaluations (available from the authors upon request). 10-point evaluation scale was applied for the questionnaire. The total sample size was 200; the survey was conducted in January and February, 2014.

Structural equation modeling (SEM) using partial least squares (PLS) path modeling methodology with SmartPLS v.2 software and descriptive statistics using SPSS Statistics v.20 software were applied for statistical analysis.

Results and Discussion

In order to assess manifest variables of the measurement model as reliable, the outer loadings among latent variables and their corresponding manifest variables have to be above 0.7. The cross loadings are provided in Table 1, as well as outer loadings (loadings of latent variable with the corresponding manifest variables). None of the outer loadings are lower than 0.7, indicating that all of the manifest variables used in the theoretical model are considered as reliable.

According to Hair et al. (2011), non-significant impacts do not support the proposed causal relationship. As the research results revealed, 'accommodation and

Table 1

Cross Loadings

Manifest variable	A.C.	A.D.	D.A.	D.M.	E.P.	L.	N.F.	P.V.	S.
Accommodation & Catering_1	0.8675	0.3784	0.3244	0.4861	0.3958	0.4955	0.3618	0.3846	0.5102
Accommodation & Catering_2	0.9057	0.3524	0.298	0.5795	0.5754	0.5023	0.5031	0.4098	0.5899
Activities in Destination_1	0.3911	0.9294	0.4066	0.4919	0.5284	0.4651	0.5522	0.4173	0.4881
Activities in Destination_2	0.3577	0.9	0.4901	0.4166	0.3467	0.381	0.3318	0.3416	0.3561
Customer Satisfaction_1	0.6026	0.4053	0.3345	0.7849	0.6968	0.749	0.6603	0.6823	0.8808
Customer Satisfaction_2	0.5458	0.4131	0.3996	0.6399	0.6922	0.7298	0.6016	0.6474	0.8783
Customer Satisfaction_3	0.4788	0.4034	0.5169	0.5639	0.5253	0.7561	0.4191	0.7178	0.8573
Customer Loyalty_1	0.5653	0.4194	0.4223	0.6725	0.6373	0.9551	0.5836	0.7548	0.8216
Customer Loyalty_2	0.5107	0.4706	0.4225	0.6428	0.6026	0.9577	0.5527	0.822	0.8124
Destination Aesthetics_1	0.3331	0.3877	0.8561	0.34	0.2413	0.3629	0.2577	0.3199	0.4084
Destination Aesthetics_2	0.2556	0.4338	0.8994	0.3081	0.2805	0.3397	0.1963	0.302	0.3564
Destination Aesthetics_3	0.3251	0.4564	0.887	0.3609	0.3799	0.4472	0.2625	0.4074	0.476
Destination Marketing_1	0.4377	0.4126	0.3012	0.8723	0.6603	0.541	0.5214	0.4629	0.6671
Destination Marketing_2	0.622	0.4676	0.3757	0.8942	0.641	0.6684	0.5716	0.5753	0.6797
Environmental Preservation_1	0.5011	0.4176	0.3024	0.6802	0.8825	0.5575	0.6141	0.4587	0.6477
Environmental Preservation_2	0.488	0.4317	0.2773	0.6285	0.8959	0.5593	0.7011	0.494	0.6391
Environmental Preservation_3	0.4602	0.4213	0.3307	0.6124	0.8347	0.5777	0.5932	0.4361	0.628
Natural Features_1	0.4211	0.4057	0.2434	0.5556	0.6564	0.5474	0.8578	0.4824	0.6348
Natural Features_2	0.4702	0.4146	0.2441	0.5347	0.637	0.5385	0.876	0.4925	0.5564
Natural Features_3	0.3502	0.4404	0.2065	0.4791	0.5525	0.4059	0.8056	0.3775	0.4245
Perceived Value_1	0.4154	0.4004	0.3421	0.5357	0.4714	0.7581	0.4877	0.9278	0.708
Perceived Value_2	0.4195	0.3779	0.3941	0.5627	0.5171	0.7775	0.5127	0.9343	0.7481

Note: A.C. = accommodation and catering; A.D. = activities in destination; D.A. = destination aesthetics; D.M = destination marketing; E.P. = environmental preservation; L. = loyalty; N.F. = natural features; P.V. = perceived value; S. = satisfaction.

catering' has a non-significant direct effect on 'loyalty' and non-significant direct, as well as total effect on 'perceived value' (see Table 2). Variable 'activities in destination' directly influences 'destination marketing' only, and has neither direct nor total statistically significant influence on other variables defined in the theoretical model. Variable 'destination aesthetics' has neither direct nor total significant effect on 'destination marketing', non-significant direct impact on 'loyalty'. Variable 'destination marketing' has non-significant direct effect on 'loyalty'. Despite this, latter variable has statistically significant direct and total effect on 'satisfaction' as well as on 'perceived value'. Variable 'environmental preservation' has non-significant direct as well as total effect on 'perceived value' and non-significant direct influence on 'loyalty'. The only statistically significant direct effect of variable 'natural features' is to variable 'perceived value'; others direct relations regarding this variable are statistically non-significant.

Consequently, all relations that were identified as non-significant were eliminated from the theoretical model and it was redesigned only with statistically significant relations for the further analysis. Additionally, the redesigned model is the basis for the new PLS Path model of rural tourist satisfaction index, which contains all the latent variables from the theoretical model; despite this, the structural equations of the model have changed.

All values of AVE (see Table 3) are high above 0.5, indicating the sufficient degree of convergent validity of the new redesigned PLS Path model regarding reflective outer model. The latter model also displays internal consistency reliability, revealed by composite reliability and Cronbach's alpha values being above 0.7. Values of communality are greater than 0.7; hence the quality of the measurement model for each block is sufficient. The R Square values show the endogenous constructs' explained variances. The lowest value of R Square is 0.43 (variable – 'perceived value'), though this value is sufficient to consider it as moderate. The explained variances of the variables 'destination marketing', 'loyalty' and 'satisfaction' are considered as high.

Discriminant validity of reflective measurement model is assessed by two criteria (Henseler et al.,

Table 2

Path Coefficients, Total Effects and their significances in the theoretical model

Latent variables	Path Coefficient	T Statistics	Total Effect	T Statistics
Accommodation and Catering -> Destination Marketing	0.2381	3.7399	0.2381	3.7399
Accommodation and Catering -> Loyalty	0.0515	1.2362	0.2183	3.4701
Accommodation and Catering -> Perceived Value	0.0603	0.7955	0.1344	1.9525
Accommodation and Catering -> Satisfaction	0.136	2.9627	0.246	4.3299
Activities in Destination -> Destination Marketing	0.1388	2.2815	0.1388	2.2815
Activities in Destination -> Loyalty	0.025	0.6164	0.044	0.542
Activities in Destination -> Perceived Value	0.0273	0.2848	0.0568	0.5402
Activities in Destination -> Satisfaction	-0.0667	1.5066	-0.0216	0.2916
Destination Aesthetics -> Destination Marketing	0.0688	1.6431	0.0688	1.6431
Destination Aesthetics -> Loyalty	0.0195	0.5461	0.1861	3.1301
Destination Aesthetics -> Perceived Value	0.1675	2.4862	0.1889	2.7855
Destination Aesthetics -> Satisfaction	0.1147	3.1429	0.2106	4.3266
Destination Marketing -> Loyalty	0.048	0.7029	0.3197	3.2083
Destination Marketing -> Perceived Value	0.3111	2.907	0.3111	2.907
Destination Marketing -> Satisfaction	0.221	3.8595	0.3539	5.3236
Environmental Preservation -> Destination Marketing	0.4582	5.482	0.4582	5.482
Environmental Preservation -> Loyalty	0.0455	0.7362	0.2979	3.8528
Environmental Preservation -> Perceived Value	0.0245	0.2526	0.1671	1.8703
Environmental Preservation -> Satisfaction	0.2245	3.6408	0.3971	5.7236
Natural Features -> Destination Marketing	0.103	1.2335	0.103	1.2335
Natural Features -> Loyalty	0.0046	0.076	0.1964	2.3247
Natural Features -> Perceived Value	0.2374	2.6287	0.2694	2.917
Natural Features -> Satisfaction	0.0498	0.8872	0.1877	2.5794
Perceived Value -> Loyalty	0.4094	5.7164	0.5836	11.152
Perceived Value -> Satisfaction	0.4273	10.3557	0.4273	10.3557
Satisfaction -> Loyalty	0.4078	4.3856	0.4078	4.3856

Table 3

Values of AVE, Composite Reliability, R Square, Cronbach's Alpha and Communalities

Latent variable	AVE	Composite Reliability	R Square	Cronbach's Alpha	Communalities
Accommodation and Catering	0.7864	0.8804	0	0.73	0.7864
Activities in Destination	0.8368	0.9111	0	0.8063	0.8368
Destination Aesthetics	0.7762	0.9123	0	0.857	0.7762
Destination Marketing	0.7802	0.8765	0.611	0.7189	0.7802
Environmental Preservation	0.7594	0.9044	0	0.841	0.7594
Loyalty	0.9147	0.9555	0.7927	0.9068	0.9147
Natural Features	0.7174	0.8838	0	0.8041	0.7174
Perceived Value	0.8668	0.9287	0.4259	0.8465	0.8668
Satisfaction	0.7607	0.9051	0.8044	0.8427	0.7607

Table 4

Latent variables' correlations

Latent variable	A.C.	A.D.	D.A.	D.M.	E.P.	L.	N.F.	P.V.	S.
Accommodation and Catering	1	-	-	-	-	-	-	-	-
Activities in Destination	0.4103	1	-	-	-	-	-	-	-
Destination Aesthetics	0.3492	0.4857	1	-	-	-	-	-	-
Destination Marketing	0.6042	0.4994	0.3848	1	-	-	-	-	-
Environmental Preservation	0.5549	0.486	0.348	0.7358	1	-	-	-	-
Loyalty	0.5621	0.4657	0.4416	0.6874	0.6479	1	-	-	-
Natural Features	0.4932	0.4926	0.2745	0.6197	0.7299	0.5938	1	-	-
Perceived Value	0.4484	0.4177	0.396	0.5902	0.5314	0.8249	0.5375	1	-
Satisfaction	0.6229	0.4668	0.4765	0.7623	0.7326	0.8541	0.6443	0.7824	1

Note: A.C. = accommodation and catering; A.D. = activities in destination; D.A. = destination aesthetics; D.M = destination marketing; E.P. = environmental preservation; L. = loyalty; N.F. = natural features; P.V. = perceived value; S. = satisfaction.

2009). The first one is Fornell-Lacker criterion, which postulates that latent construct should share more variance with its assigned indicators than with another latent variable in the structural model. The second criterion is cross loadings, specifying that an indicator's loading with its associated latent construct should be higher than its loadings with all the remaining constructs. In this case, discriminant validity of the model is ensured: the AVE of each latent variable is higher than the squared correlations with all other latent variables (see Table 4 for latent variables' correlations); all indicators' loadings with their associated latent constructs are higher than their cross loadings (see Table 1 for cross loadings). Consequently, reflective measurement model is considered as reliable and valid with reference to discriminant validity, convergent validity, internal consistency reliability and indicator reliability.

The effect sizes of the exogenous variables are provided in Table 5. 'Destination aesthetics' and 'accommodation and catering' have small effect sizes on 'satisfaction'; 'activities in destination' has small effect size on 'destination marketing' and 'destination marketing' has small effect size on 'perceived value'. Despite this, all above mentioned effect sizes are above 0.02 and all the Betas of these relations are significant, implying that these effects are meaningful. Variable 'environmental preservation' has moderate effect size on 'satisfaction', as well as variable 'accommodation and catering' on 'destination marketing'. The effect size of the variable 'environmental preservation' on variable 'destination marketing' is large.

Table 5

Effect size f^2

Latent variables	f^2
Destination Aesthetics -> Satisfaction	0.03
Environmental Preservation -> Satisfaction	0.128
Accommodation and Catering -> Satisfaction	0.051
Environmental Preservation -> Destination Marketing	0.429
Accommodation and Catering -> Destination Marketing	0.11
Activities in Destination -> Destination Marketing	0.036
Destination Marketing -> Perceived Value	0.052

When evaluating cross-validated redundancy measures for the endogenous latent variables, the chosen omission distance d was 7 (200 / 7 ≠ integer). All cross-validated redundancy values (Q^2) for endogenous latent variables are above zero (see Table 6). Consequently, structural model is able to provide a prediction of the endogenous latent variable's indicators. Therefore, the model is assessed as displaying predictive relevance.

Table 6

Stone-Geisser's Q^2

Latent variable	SSO	SSE	1-SSE/SSO
Destination Marketing	400	209.6596	0.4744
Loyalty	400	113.0665	0.7173
Perceived Value	400	252.5009	0.3619
Satisfaction	600	233.1654	0.6067

Final path coefficients, total effects and their statistical significances are provided in Table 7. Variable 'accommodation and catering' directly statistically significantly impacts 'destination marketing' and 'satisfaction'. 'Activities in destination' directly statistically significantly influences 'destination marketing'; 'destination aesthetics'; and 'destination marketing' directly statistically significantly influences the same variables – 'perceived value' and 'satisfaction'. Variable 'environmental preservation' directly statistically significantly affects 'destination marketing' and 'satisfaction'; 'natural features' – 'perceived value'. Variable 'perceived value' directly statistically significantly influences both variables: 'satisfaction' and 'loyalty'. Variable 'satisfaction' directly statistically significantly influences 'loyalty' and this influence is the highest in the model. Variable 'activities in destination' has non-significant total effect on 'perceived value'; however, it has significant total effects on 'destination marketing', 'loyalty' and 'satisfaction'. All other total effects, provided in Table 7, are statistically significant.

Consequently, the elaborated model contains five exogenous latent variables and four endogenous latent variables. The value of global criterion of goodness-of-fit (GoF) is 0.726. Accordingly, GoF index value is large. As a result, the global model evaluation is positive.

Index values of latent variables are provided in Table 8. The lowest evaluated variable is 'destination aesthetics'. Latter variable falls to low management

Table 7

Path Coefficients, Total Effects and their significances of the elaborated model

Latent variables	Path Coefficient	T Statistics	Total Effect	T Statistics
Accommodation and Catering -> Destination Marketing	0.2548	4.1414	0.2548	4.1414
Accommodation and Catering -> Loyalty	-	-	0.1593	4.1074
Accommodation and Catering -> Perceived Value	-	-	0.0898	3.0639
Accommodation and Catering -> Satisfaction	0.135	2.915	0.2287	4.3067
Activities in Destination -> Destination Marketing	0.1388	2.2815	0.1388	2.2815
Activities in Destination -> Loyalty	-	-	0.0472	2.0065
Activities in Destination -> Perceived Value	-	-	0.0489	1.7579
Activities in Destination -> Satisfaction	-	-	0.051	2.1557
Destination Aesthetics -> Loyalty	-	-	0.1688	3.7684
Destination Aesthetics -> Perceived Value	0.1869	2.9223	0.1869	2.9223
Destination Aesthetics -> Satisfaction	0.0928	2.7501	0.1735	4.0462
Destination Marketing -> Loyalty	-	-	0.3401	6.7662
Destination Marketing -> Perceived Value	0.3523	4.6693	0.3523	4.6693
Destination Marketing -> Satisfaction	0.2155	3.7461	0.3676	6.5858
Environmental Preservation -> Destination Marketing	0.527	8.5624	0.527	8.5624
Environmental Preservation -> Loyalty	-	-	0.307	7.5256
Environmental Preservation -> Perceived Value	-	-	0.1856	4.115
Environmental Preservation -> Satisfaction	0.2374	4.6239	0.4311	8.7759
Natural Features -> Loyalty	-	-	0.1704	3.2551
Natural Features -> Perceived Value	0.2679	3.3286	0.2679	3.3286
Natural Features -> Satisfaction	-	-	0.1157	3.1211
Perceived Value -> Loyalty	0.4037	6.1368	0.6361	14.6951
Perceived Value -> Satisfaction	0.4318	10.2057	0.4318	10.2057
Satisfaction -> Loyalty	0.5383	8.3422	0.5383	8.3422

level. Variables 'activities in destination', 'accommodation and catering', 'perceived value' and 'satisfaction' are evaluated at the average level. Variables 'destination marketing', 'environmental preservation', 'natural features' and 'loyalty' are evaluated a little better, though do not reach the high level. Consequently, it could be stated that current tourist satisfaction with rural destinations in Lithuania is at the average level. Moreover, loyalty of tourists to the rural destinations in Lithuania also attains only the average level.

Table 8

Index values of latent variables

Latent variable	Index value
Accommodation and Catering	72.3
Activities in Destination	68.5
Destination Aesthetics	61.6
Destination Marketing	77.2
Environmental Preservation	77.9
Loyalty	77.1
Natural Features	78.3
Perceived Value	73.9
Satisfaction	74.6

Considering that both: measurement and structural models were assessed as valid and reliable, structural equations representing the elaborated rural tourist satisfaction index model are (5-8):

(5) Destination marketing = β_{60} + β_{61} Accommodation and catering + β_{62} Activities in destination + β_{65} Environmental preservation + ζ_6;

(6) Perceived value = β_{70} + β_{73} Natural features + β_{74} Destination aesthetics + β_{76} Destination marketing + ζ_7;

(7) Satisfaction = β_{80} + β_{81} Accommodation and catering + β_{84} Destination aesthetics + β_{85} Environmental preservation + β_{86} Destination marketing + β_{87} Perceived value + ζ_8;

(8) Loyalty = β_{90} + β_{97} Perceived value + β_{98} Satisfaction + ζ_9.

Model contains five exogenous latent variables: 'destination aesthetics', 'environmental preservation', 'accommodation and catering', 'activities in destination', 'natural features'; and four endogenous latent variables: 'destination marketing', 'perceived value', 'satisfaction', 'loyalty'.

The determinants of rural tourist satisfaction are: 'accommodation and catering', 'destination aesthetics', 'environmental preservation', 'destination marketing' and 'perceived value'. Two of these determinants are endogenous, signifying that in order to enhance these variables, 'activities in destination' (affects 'destination marketing') and 'natural features' (affects 'perceived value') should be also taken into consideration. The determinants of rural tourists' loyalty are: 'satisfaction' and 'perceived value'. Latter variables are endogenous; accordingly, pursuing to enhance tourists' loyalty, not only 'satisfaction' and 'perceived value' should be managed, but also variables, that directly influence 'satisfaction' and 'perceived value'. Consequently, due to the great direct positive and significant effects of 'satisfaction' and 'perceived value' on 'loyalty', improving one or more determinants of 'satisfaction' and/or 'perceived value' would have indirect and positive effect on rural tourists' loyalty.

Bearing in mind that 'accommodation and catering', 'activities in destination', and 'environmental preservation' affect 'destination marketing', it could be stated that rural tourists in Lithuania value the benefits of 'green marketing', amenities and the efforts to create opportunities for variety of activities and the emphasis of all these aspects is perceived as 'destination marketing' by rural tourists in Lithuania. Accordingly, these aspects affect rural tourist satisfaction, as well as loyalty through variable 'destination marketing'.

Since variable 'destination aesthetics' directly influences 'satisfaction' and 'perceived value', it could be stated that rural tourists in Lithuania associate aesthetics with quality on the subject of rural destinations. As a result, with the higher level of 'aesthetics', the level of 'perceived value' also becomes higher. Consequently, latter variable directly influences tourists' satisfaction and loyalty.

Taking under consideration that 'destination aesthetics' is important determinant of tourists' 'satisfaction' and that the score of this variable is the lowest, the supposition could be made that the current level of aesthetics in Lithuanian rural destinations is insufficient. Furthermore, it could be stated that tourists are missing the wider range of activities in rural destinations, as well as a better quality of accommodation and catering. Enhancing these aspects could result in higher satisfaction and loyalty levels of rural tourists and that would contribute to the rural tourism development.

Conclusions

Rural tourism development is an important issue for many countries, including Lithuania. Achieving to develop tourism industry, tourist satisfaction becomes a considerable goal for many countries. Tourist satisfaction is evaluated by the tourist satisfaction index, which is reflected by the satisfaction index model. Wide variety of national and international tourism-related satisfaction index models can be found in the world; however Lithuania still lacks substantial research findings in the area.

Research results highlighted that the determinants of Lithuanian rural tourist satisfaction are: 'accommodation and catering', 'destination aesthetics', 'environmental preservation', 'destination marketing' and 'perceived value'. Rural tourists in Lithuania value the benefits of 'green marketing', amenities and the efforts of expanding the variety of activities; and the emphasis of all these aspects is perceived as 'destination marketing'. Tourists are missing the wider range of activities in rural destinations; a better quality of accommodation and catering; the current level of aesthetics in Lithuanian rural destinations is insufficient. Enhancing these aspects could result in higher satisfaction and loyalty levels of rural tourists and that would contribute to the rural tourism development.

References

1. Baležentis T., Kriščiukaitienė I., Baležentis A., Garland R. (2012) Rural tourism development in Lithuania (2003 – 2010) — A quantitative analysis. *Tourism Management Perspectives*, 2(3), pp. 1 – 6.
2. Chang T.-Z. (2009) Sustainability as Differentiation Tool in Destination Branding: An Empirical Study. In: Dioko L.A.N., Li X.L. (eds). *Proceedings of the 3rd International Conference on Destination Branding and Marketing*, Institute for Tourism Studies, Colina de Mong-Ha, Macao SAR, China, pp. 121 – 129.
3. Grigaliūnaitė V., Pilelienė L. (2013) Customer Satisfaction with Catering Services in Lithuania. *Regional Formation and Development Studies*, 3(11), pp. 75 – 87.
4. Hair J.F., Ringle C.M., Sarstedt M. (2011) PLS-SEM: Indeed a Silver Bullet. *Journal of Marketing Theory and Practice*, 19(2), pp. 139 – 152.
5. Hassan S.B., Hamid M.S.A., Bohairy H.A. (2010) Perception of Destination Branding Measures: A Case Study of Alexandria Destination Marketing Organizations. *International Journal of Euro-Mediterranean Studies*, 3(2), pp. 269 – 288.
6. Haven-Tang C., Jones I. (2012) Local leadership for rural tourism development: A case study of Adventa,Monmouthshire, UK. *Tourism Management Perspectives*, 4, pp. 28 – 35.
7. Henseler J., Ringle C.M., Sinkovics R.R. (2009) The Use of Partial Least Squares Path Modeling in International Marketing. *Advances in International Marketing*, 20, pp. 277 – 319.
8. Lalromawia K.K., Ramana V. (2013) An Empirical Study of the Impact of Marketing Mix Factor on Tourist Satisfaction: A Case of Selected Three States in India. *International Journal of Business Strategy*, *13*(1), pp. 87 – 94.
9. Pilelienė L., Grigaliūnaitė V. (2013) Determination of Customer Satisfaction with Supermarkets in Lithuania. *Management of Organizations: Systematic Research*, 66, pp. 99 – 114.
10. Pilelienė L., Grigaliūnaitė V. (2014) Lietuvos turistų pasitenkinimo indekso modelis: teorinės įžvalgos (Elaboration of Lithuanian tourist satisfaction index model: theoretical insights). *Management of Organizations: Systematic Research*, pp. 69. (in Lithuanian).
11. Petter S., Straub D., Rai A. (2007) Specifying Formative Constructs in Information Systems Research. *MIS Quarterly*, 31(4), pp. 623 – 656.
12. Rid W., Ezeuduji I.O., Pröbstl-Haider U. (2014) Segmentation by motivation for rural tourism activities in The Gambia. *Tourism Management*, 40, pp. 102 – 116.
13. Selladurai M.M., Sundararajan K.K. (2013) A Study On Satisfaction Of Tourists Visiting Yercaud Of Salem District. *Asia Pacific Journal of Research In Business Management*, 4(3), pp. 1.
14. Shirazi F., Mat Som A. (2013) Relationship Marketing and Destination Loyalty: Evidence from Penang, Malaysia. *International Journal of Management & Marketing* Research, 6(1), pp. 95 – 106.
15. Žalys L., Žalienė I., Iždonaitė I. (2006) Lietuvos kaimo turizmo charakteristika ir plėtros politika (Characteristics of Lithuanian Tourism and its Development Policy). *Ekonomika ir vadyba: aktualijos ir perspektyvos*, 2(7), pp. 180 – 188. (in Lithuanian).

INTERNAL FRAGMENTATION OF AGRICULTURAL PARCELS

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Abstract
Land fragmentation is a problem for many post-communist countries. Different aspects of land fragmentation have been investigated by many researchers. However, there is little attention paid to the issues of internal fragmentation of agricultural parcels. In this study, internal fragmentation is understood as the following phenomenon: a parcel consists of different types of land plots or one land type (e.g. arable land) is split into separated plots. In this study the empirical test of internal fragmentation of arable land inside agricultural parcels has been made. The aim of the study was to examine the existence and extent of internal fragmentation of agricultural parcels. The digital map of boundaries of arable land parcels and data about land types (arable land, roads, etc.) from the Estonia National Topographic Database were the data sources of the study. The following characteristics were calculated in a GIS environment for agricultural parcels: compactness coefficient; number of pieces of arable land inside a parcel; Januszewski index for characterization of internal land fragmentation and the ratio (in percent) of arable land in a parcel. The results of the study show the existence of internal fragmentation of arable land inside agricultural parcels. Arable land is internally fragmented in about 30 percent of agricultural parcels. The area of the arable land plot inside parcels is 7.7 hectares if there is no internal fragmentation. In the case of internal fragmentation of the arable land, this area is 5.6 hectares respectively.
Key words: land fragmentation, internal fragmentation, arable land, parcel.

Introduction

Land fragmentation is a many-sided feature and has been a topic of study for many researchers. Some studies have focused on the impact of land fragmentation on land use efficiency. Tan et al. (2010) studied the impact of land fragmentation on the efficiency of rice production while del Corral et al. (2011) investigated the impact of land fragmentation on milk production. Austin et al. (2012) and Latruffe and Piet (2013), for example, explored the link between land fragmentation and general agricultural efficiency. Jia and Petrick (2013) did research on the impact of land fragmentation on the off-farm labor supply. Relationships between land fragmentation and land consolidation are also topics of studies. The studies of Demetriou et al. (2012), Niroula and Thapa (2005) and Van Dijk (2004) are just a few examples.

Studies on the extent, the character and the causes of land fragmentation are important for post-communist countries where property rights on land have been changed fundamentally. The authors of those studies are from Central and Eastern Europe (e.g. Boliari, 2013; Maasikamäe, 2005; Platonova and Jankava, 2012) and from Western Europe (e.g. Van Dijk, 2003; Hartvigsen, 2013). The list of such examples can be continued.

Two central questions are related to most land fragmentation studies. The first question is about the nature of land fragmentation (What is land fragmentation?) and the second question deals with the measurement of land fragmentation (How should land fragmentation be measured?). People with different professional backgrounds and different research interests are looking at fragmentation from different points of view. Geographers (e.g. Gulinck, 2002; Taylor, 2002) investigated landscape fragmentation. There can also be emphasis on nature protection issues (Meyer and Miller, 2002; Olff and Ritchie, 2002). Landscape fragmentation can also be studied from an urbanization point of view (Hidding, 2002).

Land surveyors and land managers have usually understood land fragmentation as a type of land ownership where numerous separate parcels in a single farm are often wide apart from each other (Bentley, 1987). It is possible that one property belongs to many owners, which also is considered to be a type of land fragmentation. Van Dijk (2003) distinguishes four different types of land fragmentation when analyzing the phenomenon in Central Europe. However, internal land fragmentation as one aspect of fragmentation has been without necessary attention. The problem of internal fragmentation has been briefly discussed by Maasikamäe (2005). The problem was explained in this study, but no research about the extent of internal fragmentation has been made. The possibilities for measuring land fragmentation are presented in a concentrated way, for example, by Bentley (1987). Demetriou et al. (2012) developed further land fragmentation measurement methodology.

We understand internal fragmentation as a phenomenon by which one cadastral unit (in a further parcel) is divided into smaller plots of different type land. Internal fragmentation means that at least two different land types (for example, arable land and grassland) must be inside the parcel. There are two basic approaches for studies of internal land fragmentation. All land types will be included in the study in the first case. The second approach is to focus on a particular land type, for example, arable land. It is not a question of right or wrong choices. The

choice depends on the purpose of the investigation. Januszewski or Simmons index can be implemented for measuring internal fragmentation in both cases. These indexes are well-known and widely used for measuring the fragmentation of properties that consist of several parcels. In the case of property fragmentation, which consists of separated parcels, and in the case of internal land fragmentation, we look at the parcel that consists of separated plots of land inside them.

The focus of this study is the internal fragmentation of the arable land inside agricultural parcels. The aim of this study is to examine the existence and extent of internal fragmentation of arable land in agricultural parcels. The study is meant to create the first conceptualization about the internal fragmentation of arable land inside parcels. The study does not investigate connections of internal land fragmentation and other spatial properties of parcels.

Materials and Methods

The data for the study were the boundaries of arable land parcels (by May 2012) in ESRI shape format and data about land types (arable land, roads, etc.) from the Estonia National Topographic Database (henceforth referred to as ENTD). The total number of agricultural land parcels for Tartu County was 20241 with a total area of 241922 ha. The arable land area on those parcels was about 87150 hectares. The parcels with a total area of less than three hectares and parcels with a ratio of arable land less than five percent were excluded from the study. Parcels with a small area and low ratio of arable land are not important from the point of view of modern agriculture. The final number of parcels included in the study was 8785 with a total area of 120466 hectares. The area of arable land in those parcels is 82871 hectares.

Analysis was done with ArcGIS 10.2 software. The central map for the study was the map of the arable land parcels boundaries. All information was finally connected to the map of agricultural parcels. The procedure of examination the existence and extent of internal fragmentation of arable land in agricultural parcels generally consists of four steps.

In the first step all arable land regions of the ENTD were split into parts by roads and ditches. The ArcGIS Overlay>Erase command was implemented for that purpose. The result of this step was a layer of contiguous arable land plots. The second step was creation of the map of arable land plots by agricultural land parcels. ArcGIS Overlay>Intersect command was used for that purpose. The command Data Management Tools>Features> Multipart To Singlepart was implemented also in order to eliminate multipart objects. The result of this operation was map with the connected database table that allows running the queries for calculation spatial properties (area of arable land by parcels, number of arable land plots by parcels etc.) for each parcel. The running queries were the third step of the study. The fourth step of the study was joining the results of the queries with the database of the map of agricultural land parcel boundaries. The final database of the agricultural land parcel boundaries map contained following characteristics:

- Total area of agricultural land parcel;
- Area of arable land in each parcel;
- The ratio (in percent) of arable land in the parcel;
- Number of pieces of arable land inside the parcel;
- Compactness coefficient of the parcel;
- Januszewski index for characterization of internal land fragmentation.

Formula 1 was used for calculating the coefficient of compactness:

$$K = \frac{P}{4\sqrt{S}} \quad (1),$$

here - K – denotes the coefficient of compactness,
P – denotes the actual perimeter of the plot,
S – denotes the area of the plot.

Formula 2 was used for the calculation of Januszewski index:

$$K_J = \frac{\sqrt{S}}{\sum\sqrt{s_i}} \quad (2),$$

here - K_J – denotes Januszewski index of land fragmentation,
S – denotes total area of landholding or property,
s_i – denotes the area of i-th parcel.

All calculations, including coefficient of compactness and Januszewski index, were made in a GIS environment. All results and conclusions were derived from final database of the agricultural land parcel boundaries map.

Results and Discussion

The main results of the study are presented in Table 1. The parcels are divided into five groups depending on the number of arable land plots inside parcels. For all characteristics, the total or average has been calculated as well. Almost 70 percent of investigated parcels do not have internal fragmentation of arable land. The area of those parcels is 55.5 percent out of the whole investigated area. It means that internal land fragmentation occurs in 45.5 percent of the investigated area.

Table 1

General data about investigated parcels by the number of arable land plots inside

Characteristics	Number of arable land plots in parcel					Total or average
	1	2	3	4	5 and more	
Number of parcels	6143	1911	512	140	79	8785
Ratio of numbers of parcels by groups (percents)	69.9	21.8	5.8	1.6	0.9	100.0
Total area of parcels by groups (ha)	66793.6	31606.8	12541.8	4275.9	5248.7	120466
Ratio total area of parcels by groups (percents)	55.5	26.2	10.4	3.5	4.4	100.0
Average parcel area (ha)	10.87	16.54	24.50	30.54	66.44	13.71
Total area of arable land by groups (ha)	47297	20631	8317	2626	4000	82871
Ratio of arable land area by groups (per cents)	57.1	24.9	10.0	3.2	4.8	100.0
Ratio of arable land in parcel (percents)	71.3	66.5	65.7	62.8	66.2	69.8
Average area of one arable land plot in parcel (ha)	7.7	5.4	5.4	4.7	8.6	6.6
Compactness of parcels	1.227	1.307	1.368	1.406	1.544	1.258
Januszewski's index	1.000	0.718	0.598	0.527	0.446	0.885

The data in Table 1 show that the average parcel area varies by groups of parcel. The average area of parcels with one arable land plot inside is more than six times smaller than the average area of parcels with five or more arable land plots inside. This finding indicates that bigger parcels tend to be internally more fragmented.

The ratio of arable land inside parcels does not vary considerably by groups of parcels. The difference between parcels with the lowest ratio of arable land (62.8 percent for parcels with four arable land plots) and the highest ration of arable land (71.3 percent for parcels with no internal fragmentation) is about 1.14 times. These findings indicate that the ratio of arable land in parcels of different groups is similar and land use conditions are comparable from this point of view.

The average area of one arable land plot in a parcel varies from 8.6 hectares (a group of parcels with five or more arable land plots) to 4.7 hectares (a group of parcels with four arable land plots). The difference is about 1.8 times. It should be mentioned that there is a trend for a decrease in the average area of one arable land plot in a parcel if compared to the first four groups of parcels in Table 1. Parcels with five or more arable land plots inside do not match this trend.

The data of Table 1 show some correlation between parcel shape and the number of arable land plots inside parcels. The more compact parcels are less internally fragmented. However, the relationship between parcel shape and internal fragmentation is a complicated phenomenon, and the data of Table 1 do not give cause for drawing conclusions. The calculated coefficients of the correlation between compactness of parcels and internal fragmentation were not statistically significant. Arable land in compact parcels can be heavily fragmented internally and, in contrast, arable land in an incompact parcel can have non-fragmented arable land.

The following three examples demonstrate the complicated character of the internal fragmentation of arable land inside parcels. Three parcels of almost 100 percent arable land are presented in Figure 1. Parcel A is quite compact in shape, parcel B is less compact, and parcel C is the most incompact. The internal fragmentation of parcels A and B is similar. Both of them have arable land divided into two parts. The arable land of parcel C is divided into three parts.

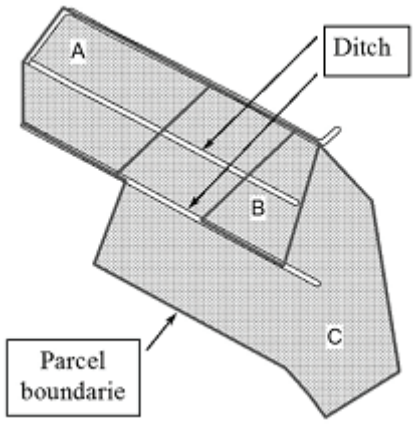

Figure 1. Example of internal fragmentation of arable land with ditches.

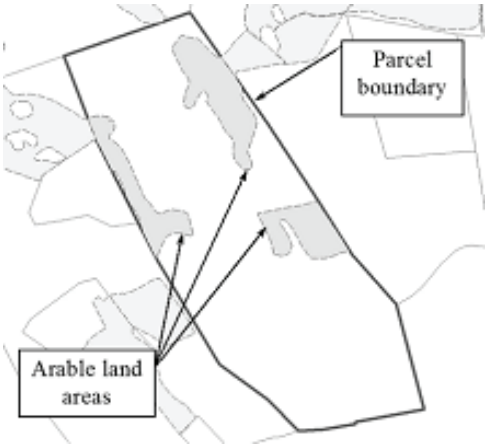

Figure 2. Example of internal fragmentation of arable land if the landscape itself is fragmented.

Figure 3. Example of a parcel with a very uncompact shape.

The example in Figure 1 shows also that it would be possible to rearrange the parcel boundaries so that arable land in all three parcels was not fragmented. The parcel boundaries should be put in line with the ditches in order to achieve non-fragmentation of arable land. The crossing of parcel boundaries with ditches is one of the reasons for arable land fragmentation.

Figure 2 presents the situation where one parcel has arable land in three plots. The parcel itself is located in the region of a fragmented landscape. Arable land areas are incompact and the ratio of arable land is not high. By visual estimations, the ratio of arable land in the region is less than 50 percent. The reduction or elimination of the internal fragmentation of arable land by changing the location of parcel boundaries would probably not be possible without changing the arable land area.

The shape of the parcels varies remarkably. The parcels' compactness coefficient in the study area was between 0.94 and 3.15. This difference is remarkable. An example of an incompact parcel is presented in Figure 3. However, internal fragmentation of arable land of the parcel in Figure 3 is similar to the parcel in Figure 2. The number of arable land plots inside the parcels is three in both cases. Land readjustment would have no effect on land fragmentation in the case presented in Figure 3.

To finalize the discussion on internal fragmentation, it should be mentioned that the shape of parcels and the location of boundaries are among the factors that have an impact on internal fragmentation of arable land inside the parcels. The study of Aasmäe (2012) showed that the small and unsuitable for cultivation plots of land can be created inside parcels if the parcel boundaries and natural boundaries do not coincide. It was mentioned also in former studies by Maasikamäe (2005) that internal fragmentation depends on the location of parcel boundaries and the fragmentation of the landscape.

It was revealed by this study that internal fragmentation of arable land in agricultural parcels exists and initial information about its extent was also discovered. The results of the study laid the foundation for future examination of internal fragmentation of agricultural parcels. The study was carried out following the example of Tartu County. Similar studies of other regions of Estonia are needed for making more solid conclusions. Local conditions (e.g. landscape fragmentation) vary by Estonian regions. The second important question is the coinciding of natural boundaries and parcel boundaries. This question was not the topic of this study but needs to be investigated in the future. The third possible question for further research is the shape of arable land plots inside parcels.

Conclusions

1. The results of the study show that internal fragmentation of arable land exists. There are two or more arable land plots inside about 30 percent (by number of parcels) of investigated agricultural parcels. About one percent of investigated parcels contain arable land in five or more pieces. The total area of agricultural parcels with more than one piece of arable land is 45 percent out of the total area of investigated agricultural parcels.
2. The average area of the arable land plot inside parcels is 7.7 hectares if there is only one arable land plot in it. The average area of the arable land plot per parcels is 5.6 hectares respectively for parcels with many arable land plots.
3. Knowledge about the extent of internal land fragmentation is an indicator for evaluating general land use conditions and the need for possible land consolidation. It is not the only indicator for that purpose, however, it is one aspect of information about land use conditions.

References

1. Aasmäe K. (2012) Looduslike piiride ja katastriüksuste piiride kokkulangemine (Coincide of property and natural boundaries). Bachelor thesis of Estonia University of Life Sciences. 43 p. (in Estonian).
2. Austin O.C., Ulunma A.C., Sulaiman J. (2012) Exploring the Link between Land Fragmentation and Agricultural Productivity. *International Journal of Agriculture and Forestry*, 2(1). pp. 30 – 34.
3. Bentley J.W. (1987) Economic and Ecological Approaches to Land Fragmentation: In Defense of a Much Maligned Phenomenon. *Annual Review of Anthropology*, 16, pp. 31 – 67.
4. Boliari N. (2013) Land Fragmentation in Bulgaria: Reconsidering Its Measurement and Extent. *Review of European Studies*, 5(1), pp. 99 – 109.
5. del Corral J., Perez J.A., Roibas D. (2011) The impact of land fragmentation on milk production. *Journal of Dairy Scienc,* 94, pp. 517 – 525.
6. Demetriou D., Stillwell J., See L. (2012) Land consolidation in Cyprus: Why is an integrated planning and decision support system required? *Land Use Policy*, 29(1). pp. 131 – 142.
7. Gulinck H., Wagendrop T. (2002) References for fragmentation analysis of the rural matrix in cultural landscapes. *Landscape and Urban Planning*, 58, pp. 137 – 146.
8. Hartvigsen M. (2014) Land reform and land fragmentation in Central and Eastern Europe. *Land Use Policy*, 36, pp. 330 – 341.
9. Hidding M.C., Teunissen A.T.J. (2002) Beyond fragmentation: new concepts for urban-rural development. *Landscape and Urban Planning,* 58, pp. 297 – 308.
10. Jia L., Petrick M. (2013) How does land fragmentation affect off-farm labor supply: panel data evidence from China. *Agricultural Economics,* 45, pp. 1 – 12.
11. Latruffe L., Piet L. (2013) Does land fragmentation affect farm performance? A case study from Brittany. Factor Markets Working Paper No. 40, 24 p., Available at: http://www.factormarkets.eu/content/does-land-fragmentation-affect-farm-performance-case-study-brittany, 10 March 2014.
12. Maasikamäe S. (2005) Assesment of Land Fragmentation. *Vagos*, 67 (20) pp. 75 – 82.
13. Meyer C.B., Miller S.L. (2002) Use of Fragmented Landscapes by Marbled Murrelets for Nesting in Southern Oregon. *Conservation Biology*, 16(3), pp. 755 – 766.
14. Niroula G.S., Thapa G.B. (2005) Impacts and causes of land fragmentation, and lessons learned from land consolidation in South Asia. *Land Use Policy,* 22, pp. 358 – 372.
15 Olff H., Ritchie M.E. (2002) Fragmented nature: consequences for biodiversity. *Landscape and Urban Planning,* 58, pp. 83 – 92.
16. Platonova D., Jankava A. (2012) Description of Land Fragmentation in Latvia and its Prevention Opportunities. *Proceedings of the Latvia University of Agriculture.* Volume 28, Issue 1, pp. 1 – 8.
17. Tan S., Heerink N., Kuyvenhoven A., Qu F. (2010) Impact of land fragmentation on rice producers' technical efficiency in South-East China. *NJAS -Wageningen Journal of Life Sciences,* 57. pp. 117 – 123.
18. Van Dijk T. (2003) Scenarios of Central European land fragmentation. *Land Use Policy,* 20. pp. 149 – 158.
19. Van Dijk T. (2004) Land consolidation as Central Europe's Panacea reassessed. In: *Proceedings of Symposium on Modern Land Consolidation*, September 10 – 11, Volvic, (Clermont-Ferrand), France, Available at: http://www.fig.net/commission7/france_2004/papers_symp/ts_01_vandijk.pdf, 10 March 2014.

THE TYPOLOGY OF PROPERTY FORMATION IN COURSE OF LAND REFORM IN ESTONIA

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Abstract
The implementation of land reform has influenced the formation of property structure. The main procedures of land reform activities are stated in Estonian legislation. However, the provisions for determining the area and the boundaries for properties to be formed in the course of land reform are stated in legal acts in an unsystematic way. The aim of this study is to systematize the parcel area and the boundaries determination procedures that are used in the course of land reform for property formation. The examination of the relationships among different property formation procedures are part of this study. The methodology of the study was a systematic analysis of the property formation procedures provided by the Estonian Land Reform Act. The results of the study show that property formation during the course of land reform can be easy and simple in some cases. In other cases, property formation may be complicated. The determination of the area and boundaries of parcels to be formed is often an issue of discretion in such cases. The results of the study support the basis for better understanding land reform outcomes. It gives some explanation of the land fragmentation that is one of the outcomes of land reform. The results of the study also serve as a basis for future studies of land reform issues.
Key words: typology, land reform, property formation.

Introduction

Different aspects have been topics of the research on land reform. The impact of land reform on agriculture has been a topic for several researchers (Unwin, 1997; Meyers and Kauzlauskiene, 1998). Hartvigsen (2014) and van Dijk (2003), for example, investigated land fragmentation as a result of land reform. Jürgenson et al. (2009, 2010 and 2011) investigated the speed of the implementation of land reform in Estonia. However, it is difficult to find literature on the procedures of property formation in the course of land reform. According to our knowledge, there are no studies in Estonia on that topic.

The determination of both area and boundary locations are the key issues in all kinds of land property formation. The location of boundaries in turn will determine several land use conditions of parcels for the future. In the text that follows property formation as a concept means both the determination of the area for new properties that were established over the course of land reform and the determination of the boundaries of such parcels.

The content of land reform is stated in article 3 of the Land Reform Act (Available at http://www.legaltext.ee/et/andmebaas/document.asp?ptyyp=RT&q2=maareformi&order=TA&tyyp=X&query=&display=1&nupp=Otsi%21). According to this act, the following basic property formation activities are prescribed:

- return of land '… to its former owners or their legal successors …' (in further text - restitution);
- transfer of land '… for or without charge into the ownership of persons in private law, legal persons in public law …' (in further text - privatization);
- transfer of land '… into the ownership of … local governments … ' (in further text – municipalisation);
- retention of land '… in state ownership is determined' (in further text - retention of land in state ownership).

Compensation for unlawfully expropriated land is also a part of land reform procedures, but it does not create a new property.

Different approaches are available for the study of land reform related property formation problems, and the analyses of property formation typology is one of them. As a rule, 'typology is the result of a grouping process (Kluge, 2000). The purpose of typology construction varies widely, and some of the following examples illustrate that. Farm typology has been constructed for reporting and research purposes (Hoppe and MacDonald, 2013). Rourke et al. (2012) worked to find if farm typologies are important for a more targeted approach to agri-environment and rural development policies. The use of typology is widely implemented in architecture and in linguistics.

The specific feature of property formation in the land reform process is the fact that the formation of one property is often related to an existing property or to a property to be created later. For this reason the focus of this study is on the investigation of property formation types and on the construction of typologies. The different options for main land reform activities (first level types of land reform procedures) are divided into more detailed options (second and third level subtypes of land reform procedures). All those options are settled in legislation. However,

legislation (e.g. the Land Reform Act) does not give the systematic typology with the subtypes of the land reform procedures. The main feature of the legal acts from the point of view of the typology is the fact that many statements that characterize particular land reform activity are stated in different articles of the legal act.

The aim of the paper is to map the main possible situations of properties formation in the course of land reform and to find out interdependencies among those situations. The key variables of the study are the determination of property area and boundaries. It should be mentioned that there are some differences of land reform procedures for urbanized (densely populated) and rural (sparsely populated) areas. The study focuses on land reform activities in rural areas. Economic, social and other technical aspects of land reform are beyond the scope of this study.

Materials and Methods

The methodology of the study is built upon the systematic analysis of four basic types of property formation that occurred during the land reform. Those basic property formation procedures have been mentioned above. The main data source for this study is the Land Reform Act, which gave basic provisions for property formation in the course of land reform. The Land Reform Act was amended 49 times, and in this study the last version (valid on 1.03.2014) of the act has been used.

The general typology of property formation activities follow directly from the Land Reform Act and it can be easily established. However, the Land Reform Act does not list all the possible combinations of property formation that can occur during the land reform. In this study the basic options (types) of property formation were split into subtypes according to the conditions for defining the property areas and boundaries. The conditions for area and boundary determination are the key variables for the creation of property formation subtypes.

The methodology of this research is not only focusing on the setting up of the property formation types and the description of them. The interdependency among the different property formation types is also analyzed. The reason for doing that arises from the fact that in the course of land reform there often was (and is) competition between different persons to acquire the same area of land. The cross table is created to show the mentioned conflicting interests.

Results and Discussion

In this part of the paper, first an overview about subtypes of the property formation procedures has been given. The main land reform activities have been divided into subtypes and the basic determinants of property formation have been presented in tables 1 to 4. Secondly, the interdependency of different property formation procedures has been provided. Finally, the general results of the study have been discussed.

The Table 1 gives an overview about the subtypes of property formation in the case of land restitution. Full restitution means that it is possible to restitute all land that was unlawfully expropriated. Other persons (including state and local governments) do not have any rights to apply for that land. This is a simple case of property formation because area and location of boundaries are unequivocally determined. However, in the case of two or more entitled subjects, the land to be restituted can be split into separated properties if the entitled subjects do not want to have co-ownership of the land. In such a case, the boundary of the division of the former property is the result of negotiations among entitled subjects of restitution.

Partial restitution can also be made (see Table 1). This is the second subtype of restitution. The reasons for partial restitution can be different. It is a simple case if there are no other persons interested in ownership of the same land plot. In other cases a contradicting interest arises and property formation procedures are more complicated. The basic reasons for partial restitution are the right of building

Table 1

Subtypes of property formation in case of land restitution

Second level subtypes of property formation	Third level subtypes of property formation	Parameters of property formation	
		Determination of parcel area	Determination of parcel boundaries
Full restitution	One entitled subject	Area of expropriated land	Boundaries of expropriated land
	Many entitled subjects	Area of expropriated land and the share of entitled subject for restitution	Boundaries of expropriated land and agreement among entitled subjects
Partial Restitution	One entitled subject	Area of expropriated land and the right of other persons to apply for land	Available for restitution land in limits of expropriated land boundaries
	Many entitled subjects		

Table 2

Subtypes of property formation in the case of land privatization

Second level subtypes of property formation	Third level subtypes of property formation	Parameters of property formation	
		Determination of parcel area	Determination of parcel boundaries
Privatization by right of pre-emption	Privatization of land to buildings in sparsely populated areas if there is vacant land	Upper limit of area set by law and the extent of former registered immovable	Boundaries of vacant land and the former registered immovable.
	Privatization of land to buildings in sparsely populated areas if there is an application for restitution of land	Upper limit of area for privatization set by law, the availability of vacant land and the extent of former registered immovable	Boundaries of vacant land and the former registered immovable
	Privatization of land to buildings in sparsely populated areas if there are many applications to privatize the same land	Upper limit of area for privatization set by law, the availability of vacant land	Boundaries of vacant land
	Privatization of land to structure if there is no building site	The land under a structure and the smallest necessary and sufficient amount of land surrounding the structure, which is necessary to ensure the purposeful and safe use of the structure	Location and purpose of the structure. Location of boundaries decided by the local government
Privatization of land on auction	Privatization of land on closed auction	Availability of vacant land and limits set by law	The existence of vacant land. Location of boundaries decided by the local government
	Privatization of land on open auction	Availability of vacant land	
	Privatization of free arable land	Availability of vacant agricultural land	
	Privatization of free forest land	Availability of vacant forest land	

owners to privatize land for building, the right of the municipality to apply land into municipal ownership in some cases and the interest of the state to retain land in state ownership. In some cases it is not possible to restitute the land because it is under road, airport, or other construction.

The privatization of land is the most diverse group of tasks among the land reform activities. Table 2 gives an overview of the main subtypes of property formation procedures related to the land privatization. Privatization of land by right of pre-emption is not a complicated task if there is vacant land. The legislation (the Land Reform Act, first of all) provides quite clear provisions for property formation in such cases. The situation becomes more complicated if there is no vacant land or the area of vacant land is insufficient. It can happen, for example, that the owner of the building applies for the privatization of land by right of pre-emption to the building, and the entitled subject of restitution wants to get back the land. Such cases lead to partial restitution, which was discussed earlier.

The second subtype for land privatization in the course of land reform is through auction. The auctions can be closed or open. The main precondition for formation of properties for privatization via auctions is the availability of vacant land. It is valid for all subtypes of the privatization of land on auction. However, the parcels prepared for privatization must meet some criteria set by the law. For example, the parcel for privatization as free arable land must consist of mainly arable land. The inclusion of other land types into such parcels is very limited.

The subtypes of property formation for municipalization are presented in Table 3. The distinction among different possibilities for land municipalization has been made on the second level only. The possibilities for property formation are quite clearly provided in law. The formation of land properties for buildings that belong to the local government is settled clearly in law and there is no need for discretion, for example. Somewhat unclear is the formation of properties in the case of agricultural land, necessary for the performance of the duties of an agency administered by a local government.

The main subtypes of property formation for the retention of land for state ownership are presented in

Table 3

Subtypes of property formation in case of land municipalization

Second level subtypes of property formation	Parameters of property formation	
	Determination of parcel area	Determination of parcel boundaries
Parcels of land for buildings and structures in municipal ownership	The area is determined by the needs for serving the buildings and structures	Location and the purpose of the building or the structure.
Parcels of land under water bodies in municipal ownership and public land	The actual extent of the body of or the location of public land or the planned area of public land	Location of the body of water or the location of public land or the planned area of public land
Parcels of agricultural land necessary for the performance of the duties of an agency administered by a local government	Not settled clearly in law	Not settled clearly in law
Parcels of land which were in the ownership of a local government on 16 June 1940 or common land which was in the ownership of a village community on 16 June 1940	The area of former ownership by a local government or the area of former ownership by a village community	The boundaries of former ownership by a local government or the boundaries of former ownership by a village community
Parcels of land which are necessary for the performance of the functions and development of the local government	The area is determined by needs of local government to perform particular functions	The boundaries are determined in compliance with planning and land readjustment requirements

Table 4. The area and boundaries of state forest land on 16 June 1940 are the main determinants of property formation for state forest land parcels. The property formation of those parcels is clear and unequivocal. The property formation of parcels for land under state protection and land adjacent to objects under state protection are not always unequivocally defined. Some protected land (an area that is not so strongly protected) can be restituted or privatized, for example. It depends on the will and interests of persons who will become the owners of the area under protection.

The formation of properties for serving state-owned buildings and structures or the formation of properties with other land necessary for the performance of state

Table 4

Subtypes of property formation in case of retention land in state ownership

Second level subtypes of property formation	Parameters of property formation	
	Determination of parcel area	Determination of parcel boundaries
Parcels of state forest land	The area of a former state forest	Former boundaries of state forest and the boundaries of parcels for privatization of land to buildings
Parcels of land under state protection and land adjacent to objects under state protection	The area of land under protection or needed to serve the object under protection	The boundaries are determined by the needs of the state and decided by state authorities
Land for parcels of state-owned buildings, structures and other enterprises.	The area is determined by the needs for serving the buildings and structures or by the needs for ensuring the functioning of the state-owned enterprises or agencies	
Parcels of public land, national defense land and other land that is needed for the state	The area is determined by the needs of national defense and the needs of the state to fulfill certain duties	
Parcel of land on which a usufruct is established	The area of vacant land for creation of parcels	
Parcel of land for constitution superficies	The area that is needed for serving the building	
State land reserve	The area of vacant land (no claim for restitution, privatization, municipalization and retention in state ownership for definite purpose	The boundaries are determined with already established parcels

Table 5

Examples of interdependencies of property formation procedures

Property formation procedure	Possible constraints of property formation
Property formation for land restitution	Right of other entitled subjects for restitution of a share of the same land to be restituted
	The right of a house owner to privatize land to the building
	The presence of protected land that can not be restituted
	The need of the state to retain land in state ownership
	The right of local governments to municipalize land
Property formation for land privatization	Right of entitled subjects for restitution of the same land
	Right of other persons to privatize the same land
	The needs of the state to retain the land in state ownership
	The needs of local governments to municipalize land
Property formation for land municipalization	Right of subjects for land restitution
	The right of a house owner to privatize land to the building.
	The needs of state to retain the land in state ownership
Property formation for retention of land in state ownership	Right of subjects for land restitution
	The right of a house owner to privatize land to the building.
	The right of local governments to municipalize land

duties is decided by state authorities. The state has a prior right in such cases. The state does not have in all cases the prior right to decide the extent of the area and the location of boundaries of the land to be retained in state ownership. This is the case with state land reserves, for example.

Some examples of interdependency among different property formation procedures are presented in Table 5. The table shows the possible constraints of property formation by the main land reform procedures. Some of those interdependencies were discussed above, for example, the problems of boundary determination in the case of restitution of a former property to more than one owner. The prior right to municipalize the land or to retain the land in state ownership in the case of claims for the return of land or privatization with the right of pre-emption can be implemented only in certain cases.

The examples in Table 5 do not cover all of the possible combinations of interdependencies among property formation activities. They just illustrate the complicated nature of property formation procedures over the course of land reform.

It follows from the study that four basic land reform procedures (restitution, privatization, municipalization and retention of land in state ownership) can combine in reality in very different ways. Very often the formation of properties is not possible to do one by one. The main reason for that are the rights of different people to apply for the same pieces of land. There can be, for example, applications by more than one person for restitution and more than one person can have the right to privatize the same plot by right of pre-emption. The problem can be solved in a way that interested parties are satisfied in the case of available vacant land. However, the vacant land is not always available and property formation is a complicated process of negotiations and discretions.

In this study we also found that all property formation activities can be divided into two types depending on the rate of complexity of the particular case. The first type of case can be called easy (indubious) determination of boundaries of new parcels. Those cases can also be called simple cases. No conflict of interest and disputes about the location of boundaries among different persons exist. The second type of property boundaries determination is difficult cases. They can be also called complicated cases. The conflict of interest by different persons who want to own the same particular area of land is the main feature of difficult cases. The negotiations and consideration of different circumstances should be placed in the difficult cases and the decisions based on discretion.

The holistic analysis of property formation typology shows that procedures provided in the Land Reform Act in many cases lead to the land fragmentation. There are several provisions in law for the division of a particular plot of land among several interested parties. For example, it can be the case if there is more than one person applying for land restitution or in the case of an application for the privatization of a plot of land with an application for restitution. The knowledge of the typology of property formation procedures will support a better understanding of the results of land reform.

The results of the current study can also serve as a basis for comparative studies in future. It will be easier to compare land reform outcomes, for example, in the Baltic States, if the typology of property formation is

clearly stated and presented in a systematized format. Even though the typology of Estonian land reform procedures does not match to similar procedures in other countries, some unclear things become clearer if the typology is known.

The current study was a purely qualitative one. However, the study laid the foundation for more profound investigations of the topic in the future. The results of this study can be treated as a first step for working out an elaborated typology of property formation over the course of land reform. The current study is also the basis for different quantitative studies in future.

Conclusions

To sum up the results of the study the following conclusions can be made:

1. There are simple and complicated cases of property formation during the course of land reform. In simple cases the boundaries of properties to be formed are determined unequivocally. The typical feature of simple cases is the absence of conflicting interest among different parties. In complicated cases the location of boundaries and the extent of an area of properties to be formed are the issues of negotiation among interested parties and discretion.
2. The boundaries of properties unlawfully expropriated in 1940 and the boundaries of building sites from the Soviet period are the basic determinants of boundary location and the extent of an area for property formation in simple cases. There is no place for discretion in those cases.
3. The provisions of the Estonian Land Reform Act can often lead to the division of a particular land area among different interested parties. The division of land in such cases in turn led to land fragmentation.
4. The knowledge about the typology of property formation procedures will support the better understanding of land reform results and can be implemented as a basis of further studies.

References

1. Hartvigsen M. (2014) Land reform and land fragmentation in Central and Eastern Europe. *Land Use Policy*, 36, pp. 330 – 341.
2. Jürgenson E., Maasikamäe S. (2009) Progress of Land Reform in Estonian Rural Municipalities - Results of Preliminary Study. *In: Rural Development 2009: The Fourth International Scientific Conference Proceedings.* Volume 4, Book 2, Kaunas, pp. 121 – 127.
3. Jürgenson E., Hass H., Maasikamäe S. (2010) The Impact of Land Fund Characteristics on the Land Reform Results in Estonian Rural Municipalities. *Vagos*, 86 (39), pp. 65 – 70.
4. Jürgenson E., Hass H., Maasikamäe S. (2011) Land Reform Implementation in Estonia: Comparison of Land Reform Activity and Land Stock Characteristics Between Municipalities. *In: Rural Development 2011. The Fifth International Scientific Conference Proceedings.* Volume 5, Book 2, Kaunas, pp. 440 – 445.
5. Kluge S. (2000) Empirically Grounded Construction of Types and Typologies in Qualitative Social Research. *Forum Qualitative Sozialforschung / Forum: Qualitative Social Research*, Vol. 1, No 1 (ISSN 1438-5627). Available at: http://www.qualitative-research.net/index.php/fqs/article/view/1124/2500, 25 February 2014.
6. Land Reform Act (1991) Unoficcial translation. Available at: http://www.legaltext.ee/et/andmebaas/document.asp?ptyyp=RT&q2=maareformi&order=TA&tyyp=X&query=&display=1&nupp=Otsi%21, 1 March 2014.
7. Meyers W.H., Kauzlauskiene N. (1998) Land reform in Estonia, Latvia, and Lithuania: a comparative analysis. Land Reform in the Former Soviet Union and Eastern Europe, pp. 87 – 110.
8. Hoppe R.A., MacDonald J.M. (2013) *Updating the ERS Farm Typology,* EIB-110, U.S. Department of Agriculture, Economic Research Service, April 2013. Available at: http://www.ers.usda.gov/publications/eib-economic-information-bulletin/eib110.aspx#.UxIRnM4nYto, 20 February 2014.
9. Rourke E.O., Kramm N., Chisholm N. (2012) The influence of farming styles on the management of the Iveragh uplands, southwest Ireland. *Land Use Policy*, 29 (4), pp. 805 – 816.
10. Unwin T. (1997) Agricultural Restructuring and Integrated Rural Development in Estonia. *Journal of Rural Studies* 1, pp. 93 – 112.
11. van Dijk T. (2003) Scenarios of Central European land fragmentation. *Land Use Policy*. 20 (2), pp. 149 – 158.

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