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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 18th International Scientific Conference "Research for Rural Development 2012" held at the Latvia University of Agriculture, in Jelgava, on 16 to 18 May 2012.

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 200 researchers with very different backgrounds. There were 114 presentations from different universities of Lithuania, Estonia, Ukraine, South Africa 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 18th International Scientific Conference "Research for Rural Development 2012" is intended for academics, students and professionals researching in the area of 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 proceedings will be useful for researchers in educational sciences, too. 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 18th International Scientific Conference
"Research for Rural Development 2012"

Ausma Markevica
Latvia University of Agriculture

CONTENTS

INDIVIDUAL TREE IDENTIFICATION USING COMBINED LIDAR DATA AND OPTICAL IMAGERY

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Abstract
The most important part in forest inventory based on remote sensing data is individual tree identification, because only when the tree is identified, we can try to determine its characteristic features. The objective of research was to explore remote sensing methods to determine individual tree position using LiDAR and digital aerial photography in Latvian forest conditions. The study site was a forest in the middle of Latvia – in Jelgava district (56º39' N, 23º47' E). Aerial photography camera (ADS 40) and laser scanner (ALS 50 II) were used to capture the data. LiDAR resolution was 9p m^2 (500 m altitude). The image data is RGB, NIR and PAN spectrum with 20 cm pixel resolution. Image processing was made using Fourier transform, frequency filtering, and reverse Fourier transform. LiDAR data processing methods was based on canopy height model, Gaussian mask, and local maxima. Field measurements were tree coordinates, species, height, diameter at breast height, crown width and length. Using combined LiDAR and optical imagery data allows detecting at least 63% of all trees and about 85% of the dominant trees.
Key words: Forest inventory, tree identification, laser scanning, aerial photography, data fusion.

Introduction

Various studies concentrate on individual tree detection from different remote sensing data. An optimal tree identification method often consists of a variety of data sources that are combined with various methods (Hyyppä et al., 2008). Most common sensors for forestry measurement applications are Airborne LiDAR (Light Detection and Ranging) and digital aerial cameras. LiDAR is one of the active optical remote sensing technologies that can provide highly accurate measurements of both the forest canopy and the ground surface. It provides data that make it possible to identify and isolate individual trees. Different sensors or methods that encompass certain levels of observation should not be taken as exclusionary alternatives (Korpela et al., 2004).

The most responsible and important part in forest inventory based on remote sensing data, is individual tree identification, because only when the tree is identified, we can try to determine its characteristic features like tree species, tree height, diameter at breast height, volume, and biomass (Secord and Zakhor, 2006; Edson and Wing, 2011).

In studies of forest inventory using remote sensing sensors, one of the main problems the authors mention is tree identification and accurate determination of the tree location (Hyyppä et al., 2008; Kane et al., 2010), especially in Middle Europe (Diedershagen et al., 2006), since there is a mixture of different deciduous and coniferous trees. As a result, the indication is much harder. Many authors in their conclusions highlight that the usage of LiDAR and airphoto methods to determine forest inventory parameters will never be one hundred per cent correct (Onge et al., 2004; Rombouts, 2006), especially applying automated tracking methods (Hyyppä et al., 2004; Junttila et al., 2010). Practically for all researchers so far it has been difficult to identify small trees (Pitkänen, 2001; Pouliot and King, 2005) and close existing trees (Pouliot and King, 2005; Koch et al., 2006), as well as high density hardwood stands with homogeneous crown (Kocha et al., 2006; Rahman and Gorte, 2008). Automated tree identification and accurate determination of the tree location is still problematic (Popescu et al., 2002; Junttila et al., 2010), even in cases where access to different types of data (Vauhkonen et al., 2008) is available. This is mainly explained by the fact thattrees vary in crown size (Tokola et al., 2008), shape and optical properties (Tokola et al., 2008; Vauhkonen et al., 2008), for example, some species have rounded crowns, some have cone-shaped crowns, and some have star-shaped crowns. Tone in aerial photographs depends on many factors, and relative tones on a single photograph, or a strip of photographs may be of great value in delineating adjacent trees of different species (Kocha et al., 2006). Crowns are often interlaced. Occlusion and shading are present, and result in omission errors. These factors affect the treetop positioning and make the identification of trees difficult.

Pitkänen developed several methods for individual tree detection based on canopy height model of Airborne LiDAR. One of them he used a Gaussian filter to determine equalized height of pixel. Local maxima and smoothed Canopy Height Model were considered as tree locations. In the other method, large numbers of possible tree locations were selected based on local maxima. The pixels were reduced based on slope within the assumed crown center area and based on the distance and valley depth between a location and its neighboring locations. The second method used crown width and tree height model as a parameter to adapt with tree size. Both methods showed that about 60-70% of the dominant trees

were found (Pitkänen et al., 2004). Weinacker used local maximum of smoothed canopy height model and delineation of single tree is done using pouring algorithm. It was observed that the segmented trees still contained a lot of wrong segments, in which the regions are too small to be a tree, inappropriate crown shape, and crown regions that cover another trees and canopy gaps. The segments were refined based on their shapes and distance between tree tops (Weinacker et al., 2004). In another study, Kim used variable size of local maxima filtering window with the assumption that there is a relationship between crown size and tree height. It was shown that the regression coefficients are less than 0.6 (Kim et al., 2008). In Scandinavian countries, studies of tree location determination using LiDAR and digital aerial camera show good results. For example, Korpelas research shows that location of 2% of conifers and 10% of deciduous trees were determined inaccurately, 10% of all trees were not identified, and 12% of the total stock of wood was inaccurate (Korpela, 2006). Falkowski introduces technique based on spatial wavelet analysis to automatically estimate location, height and crown diameter of individual trees using Airborne LiDAR. The advantage of this method is that no knowledge on tree height and crown diameter relationship is required (Falkowski et al., 2006).

Numbers of different methods are used to identify a single tree using Airborne LiDAR and digital aerial cameras. Above it is clearly shown that most of the tree detection studies were based on the height of the canopy. For some approaches the relationship between crown size and tree height is needed beforehand. Single-scale template matching has been successfully applied in 2D and 3D treetop estimation of regular stands, where crowns show only moderate variation (Korpela and Tokola, 2006). In contrast, to determine all the treetops where forest foliage is complex in structure and with a large variation, the most appropriate are the automatic and semi-automatic methods (Korpela et al., 2007).

Data collection and processing methods in different conditions work variously, mainly due to forest density, represented tree species and forest diversity in growing conditions, as well as LiDAR and optical imagery. The objective of research is to explore methods to determine single tree position using LiDAR and digital aerial photography in Latvian forest conditions.

Materials and Methods

The study site was a forest (12 700 ha) in the middle of Latvia - in Jelgava district (56º39' N, 23º47' E). Totally 350 sample plots (0.045 ha) were established during the summer of 2011.

The area consists of a mixed coniferous and deciduous forest with different age, high density, complex structure, various components, composition and soil conditions.

Represented species were Scots pine (*Pinus sylvestris* L.), Norway spruce (*Picea abies* (L.) H.Karst), silver birch (*Betula péndula* Roth), black alder (*Alnus glutinos* L.), and European aspen (*Populu strémula* L.).

All trees with a diameter at breast height (DBH) of more than 5 cm were measured, and for each tree coordinates, its species, height, DBH, crown width and length were recorded. Altogether there were 6155 trees in the data. The mean characteristics of all trees are presented in Table 1.

Differentially corrected Global Positioning System measurements were used to determine the position of each plot center. The accuracy of the positioning was approximately 1 meter.

The tree crown width was measured by projecting the edges of the crown to the ground and measuring the length along one axis from edge to edge through the crown center. The diameters of any two axes at 90 degrees to each other were selected and averaged using an arithmetic mean. Tree locations within a plot were measured using center as the origin and then determining tree azimuth and distance to the center.

In data processing, effective crown area (area that does not overlap with another tree crown) for each tree (first and second storey trees equally) was calculated using information about its locations within a plot and crown width. The foliage was projected on the ground, and using the generally known area calculation formulas the effective crown area was calculated.

Data were obtained using a specialized aircraft Pilatus PC-6, which is equipped with a positioning and Geomatics technology company Leica Geosystems equipment a large format digital aerial photography camera (ADS 40) and laser scanner (ALS 50 II). The study area was flown over by plane and scanned at three different altitudes. The LiDAR digital terrain models (DTM) were estimated from leaf-on data from May, 2010, having 9 p m^{-2} at 500 m altitude. The image data are RGB (Red, Green, and Blue), NIR (Near Infrared) and PAN (Panchromatic) spectrum with 20 cm pixel resolution.

Fourier transform, frequency filtering and reverse Fourier transform were performed to each image from the previously prepared data sets. After this process, texture of image was obtained. Fourier transform function:

$$F(k,l) = \sum_{j=0}^{N-1} \sum_{j=0}^{N-1} f(i,j)\, e^{-t2\pi\left(\frac{ki}{N} + \frac{lj}{N}\right)}, \quad (1)$$

Fourier frequency filtering function:

$$G(k,l) = F(k,l)\,H(k,l), \quad (2)$$

Reverse Fourier transform function:

$$f\,(i,j) = \frac{1}{N^2}\sum_{k=0}^{N-1}\sum_{i=0}^{N-1} F(k,l)e^{\,t2\pi(\frac{ki}{N}+\frac{lj}{N})}, \quad (3)$$

where f (i,j) is the image in the spatial domain, and the exponential term is the basis function corresponding to each point F (k,l) in the Fourier space. H (k, l) is the simplest case, the threshold function that determines which frequencies to keep and which not. *N* is used for normalization.

Eight different convolutions where made with 15×15 matrix after applying a Fourier filter (matrix size is related to the projection image pixel size), in resulting image pixels where highlighted that match at specified filter. Discrete filter convolution mathematical definition is as follows:

$$F\,(i,j) = \sum_{x=0}^{m}\sum_{y=0}^{n} F'\left(i+\left(x-\frac{m}{2}\right),\right.$$
$$\left.j+\left(y-\frac{n}{2}\right)\right)K(x,y) \quad (4)$$

where F (i, j) result of image pixel; F '(i, j) the original image pixel; C (x, y) convolution filter matrix value; m, n convolution filter matrix dimensions.

Information about filter configuration was highlighted after image processing with convolution matrices. To find the peak that matches the tree center, all eight files were calculated and a single image, which retains only the pixels in the convolution execution of all eight images with the same intensity, was created. Image overlay was used to find this function:

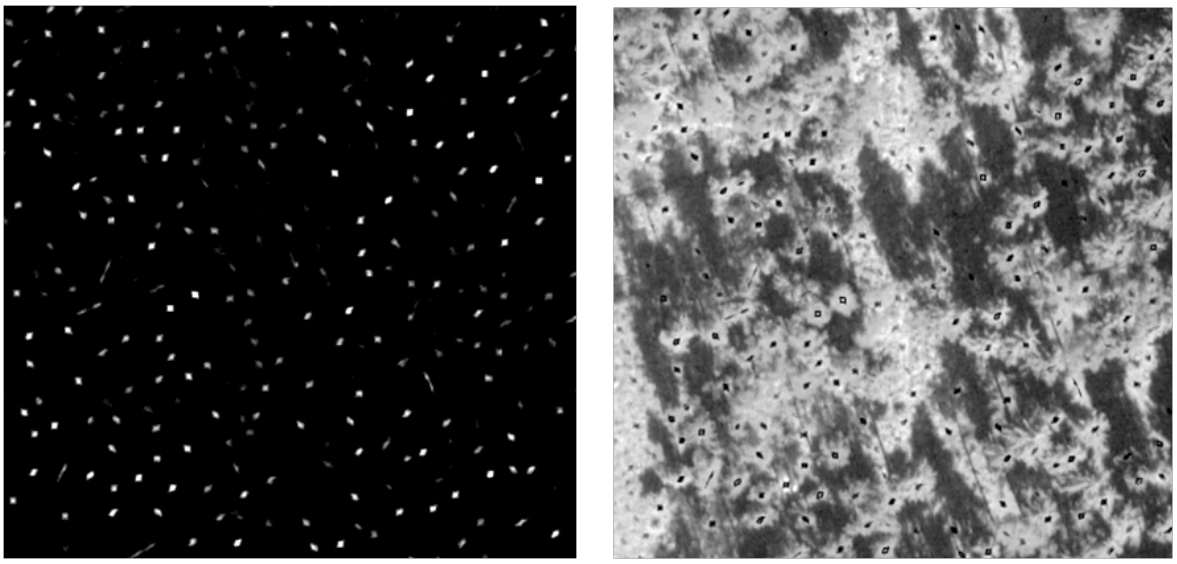
$$F(i,j) = \min\,(I(i,j), L(i,j)) \quad (5)$$

where I (i, j) and L (i, j) coated image pixel values. The result is a picture where the intensity of pixels corresponds to the largest tree in the center (Figure 1. (a)).

There are many additional points that are not only on trees, but also on other objects, therefore, it is necessary to perform data filtering. Once the information need is imported in database, it is possible to make the necessary filtering and combining operations with LiDAR tree centers. Before importing each pixel high-intensity group (which serves local maxima) are defined. Center and its geographical coordinates are calculated using the image geo-referenced data.

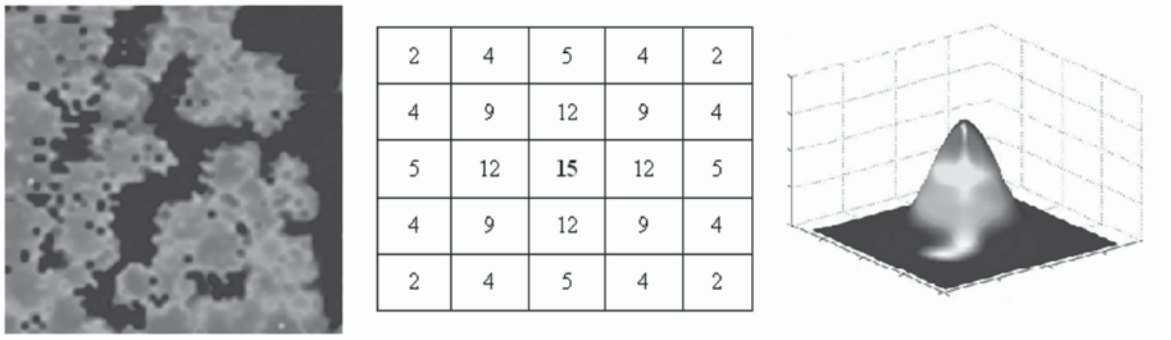
The individual tree detection and identification method is based on canopy height model. The model was smoothed using a Gaussian mask, and the degree of smoothing is defined by the height of pixel. Subsequently, local maxima on the smoothed canopy height model were considered as tree locations. Noisy data was masked (suppressed) using 5×5 Gaussian mask size (Figure 2. (c)).

With Gaussian mask each point value was calculated taking into account the impact of the points placed beside. The closest points have a greater impact, but the further - a smaller impact. In the middle of the Gaussian matrix the highest value indicating the significance is located, and this value is multiplied by the point value. After calculating the



a) Local Maxima. b) Local Maxima combined with the original image.

Figure 1. Result of convolution process.



2	4	5	4	2
4	9	12	9	4
5	12	**15**	12	5
4	9	12	9	4
2	4	5	4	2

a) Raw LiDAR data.

b) Gaussian mask matrix for a single tree.

c) Gaussian masks result for a single tree.

Figure 2. LiDAR data processing.

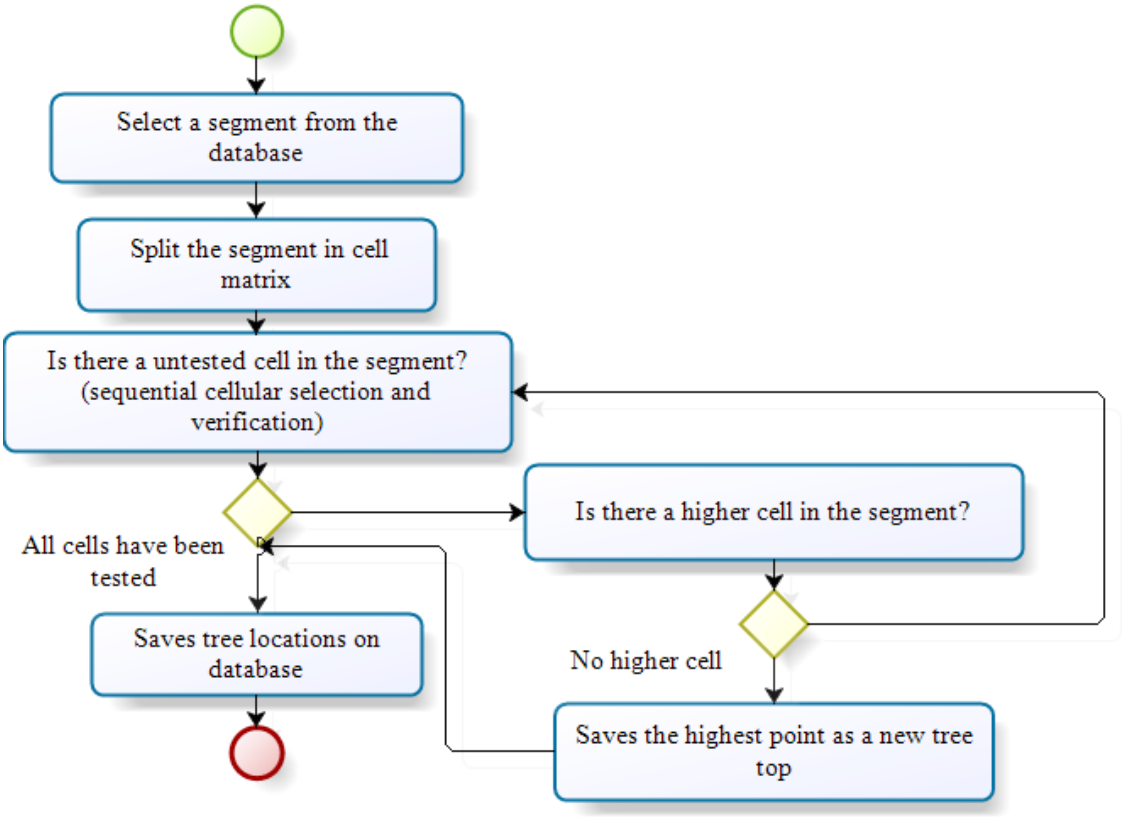


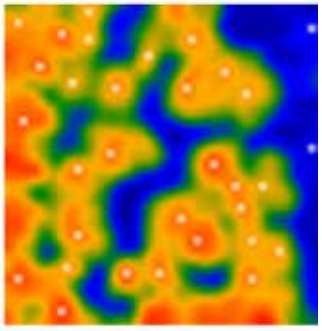
Figure 3. Tree recognition algorithm.

Gaussian mask, the highest segment points above the surface were searched and compared with adjacent cells independently of each segment. If the selected cell was higher than the adjacent, then there was the tree top. Tree top not always is the center of the cell, so the tree is found in the center of determining the highest cell. Tree recognition algorithm is shown in Figure 3.

Results and Discussion

The accuracy of tree detection was satisfactorily when we used combined LiDAR and optical imagery data. Figure 4 shows the identified tree centers detected in the canopy height model using a Gaussian mask and local maxima.

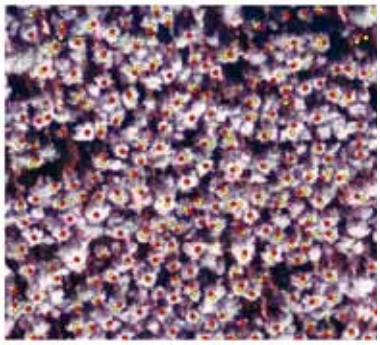
The results of identified trees using LiDAR and image data processing methods combined and separately, are showed in Figure 5. The red point shows the identified trees from an aerial photography, but the yellow one - from LiDAR. Initially, looking at these pictures it seemed that most of the trees are recognized, especially looking at the picture b), but comparing the data to field plots, omission errors were found. This was mainly caused by the large number of suppressed, small trees that were not detected from the canopy height model. The local maximum method



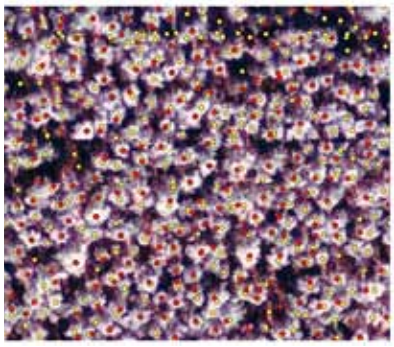
a) Tree top recognition result of Gaussian mask.

b) Tree locations produced by the local maximum and foliage segmentation methods.

Figure 4. Tree identification results using LiDAR and image processing methods separately.



a) Tree centers are determined by the LiDAR processing and image processing techniques separately.



b) Tree centers are determined combining both processing methods.

Figure 5. The results of identified trees using LiDAR and image data processing methods combined and separately.

partially recognized the second storey trees, which cannot be seen in the aerial photo, because they are obscured by trees on the first storey, but in aerial photo sometimes it is possible to see trees that are not visible in the LiDAR data, because when trees are close together LiDAR combines them.

The results of tree detection using combined LiDAR and aerial photographic method show that 63% of all trees were unambiguously found, but 37% of trees were not identified (Table 1). If we look at not identified trees, then 82% of cases were trees with diameter at breast height (DBH) less than 20 cm, and 88% of cases were trees with height less than 20 m. This means that only about 15% of first storey trees were not identified correctly.

The calculated tree centers only in 86% of cases are located in 3 m limit. This is explained by the fact that trees vary in crown size, shape and optical properties, and crowns are often interlaced. These factors affect the treetop positioning and make the identification difficult.

Descriptive statistics of tree detection result and tree characterizing parameters (combined LiDAR and optical imagery data) is shown in Table 1, and analysis of variance between tree detection result and tree characterizing parameters is shown in Table 2.

Analysis of variance between tree detection result and tree characterizing parameters shows that only tree age is not statistically significant at a different level of significance. This means that the tree height, diameter at breast height and tree crown width affect the possibilities of identifying trees from remote sensing data.

In literature, using a similar approach, the tree identification results show variable results. I. Korpelas study reveals that 91% of conifers and 86% of the deciduous trees were identified using the local maximum filtering method (Korpela, 2006), but H. Weinacker in his study found that only 54% of trees were identified correctly (Weinacker et al., 2004). At the same time, S. Kim suggests that 64% of all the trees can possibly be identified (Kim et al., 2008). In many works, the authors mention that the forest type and the dominant species are the main factors that affect tree identification possibilities (Pitkänen et al., 2004; Kocha et al., 2006; Korpela, 2006; Tokola et al., 2008).

Table 1

Descriptive statistics of tree detection result and tree characterizing parameters (combined LiDAR and optical imagery data)

Result of tree detection		Age	DBH	Tree Height	Crown Width
Trees identified	Mean	68.73	25.857	23.655	5.8929
	N	3857	3857	3857	3857
	Std. Deviation	34.308	10.1293	6.3165	2.02080
	Minimum	4	5	3.5	1.13
	Maximum	164	83.8	39.9	18.93
	% of Total N	62.7%	62.7%	62.7%	62.7%
Trees not identified	Mean	68.74	14.262	13.612	4.3950
	N	2297	2297	2297	2297
	Std. Deviation	35.099	7.2307	5.6882	1.58273
	Minimum	4	5	1.9	0.50
	Maximum	164	54.6	37.3	13.31
	% of Total N	37.3%	37.3%	37.3%	37.3%

Table 2

Analysis of variance between tree detection result and tree characterizing parameters

	Sum of Squares	Mean Square	F	Sig.
Age * Tree Detection Result	0.041	0.041	0.000	0.995
DBH * Tree Detection Result	193552.115	193552.115	2309.059	0.000
Tree Height * Tree Detection Result	145217.109	145217.109	3916.008	0.000
Crown Width * Tree Detection Result	3230.005	3230.005	924.320	0.000

Conclusions

1. Using combined LiDAR and optical imagery data it is possible to detect at least 63% of all trees and about 85% of the dominant trees. This is explained by the fact that trees vary in crown size, shape and optical properties, and crowns are often interlaced. These factors affect the treetop positioning and make the identification difficult. The problem is with the identification of the small trees and close existing trees, as well as with high - density hardwood stands with a homogeneous crown.
2. Analysis of identified trees shows that Norway spruce was not identified in 20% of cases and 55% at the species level trees were not identified. This is explained by the fact that the spruce crown geometry is triangular, and, consequently, the LiDAR - transmitted pulses often miss the highest tree point. Pine and birch crown geometry is slightly flatter, and the measurements are more accurate.
3. Latvian forest conditions are difficult for single tree remote sensing methods mainly of mixed deciduous and coniferous species with a high level of the second storey trees in one stand. Mostly trees are close together at high density and with a homogeneous crown. It is one of the main reasons for a large number of trees that are omitted.
4. To improve the recognized number of trees, one way is to perform laser scanning in spring when the forest is less dense, the first storey trees are more transparent, and the smaller dimension trees can be recognized. A second way is to use tree crown shape analyze from LiDAR data, and it means that there is a need for LiDAR data with a higher level of point density per square meter.

References

1. Diedershagen O., Koch B., Weinacker H. (2006) *Automatic Estimation of Forest Inventory Parameters Based on LIDAR, Multi-spectral and Fogis Data*. Department of Remote Sensing and Land Information Systems. Institute of Forestry Economics. University Freiburg, Germany, 10 p.
2. Edson C., Wing M.G. (2011) Airborne Light Detection and Ranging (LiDAR) for Individual Tree Stem Location, Height, and Biomass Measurements. *Remote Sensing*, 3, pp. 2494–2528.
3. Falkowski M., Smith A., Hudak A., Gessler P., Vierling L., Crookston N. (2006) Automated estimation of individual conifer tree height and crown diameter via Two-dimensional spatial wavelet analysis of lidar data. *Canadian Journal of Remote Sensing*, 32, pp. 153–161.

4. Hyyppä J., Hyyppä H., Leckie D. (2008) Review of Methods of Small-footprint Airborne Laser Scanning for Extracting Forest Inventory Data in Boreal Forests. *International Journal of Remote Sensing*, 29, pp. 339–366.
5. Hyyppä J., Hyyppä H., Litkey P. (2004) Algorithms and Methods of Airborne Laser Scanning for Forest Measurements. *Remote Sensing and Spatial Information Sciences*, 36, pp. 18–25.
6. Junttila V., Kauranne T., Leppänen V. (2010) Estimation of Forest Stand Parameters from Airborne Laser Scanning Using Calibrated Plot Databases. *Forest Science*, 56, pp. 257–270.
7. Kane V.R., Bakker J.D., Mc Gaughey R.J., Lutz J.A., Gersonde R.F., Franklin J.F. (2010) Examining conifer canopy structural complexity across forest ages and elevations with LiDAR data. *Canadian Journal of Forest Research*, 40, pp. 774–787.
8. Kim S., Schreuder G., McGaughey R.J., Andersen H.E. (2008) Individual Tree Species Identification Using LiDAR Intensity Data. Available at: http://www.asprs.org/a/publications/proceedings/portland08/0043.pdf, 4 January 2012.
9. Koch B., Heyder U., Weinacker H. (2006) Detection of Individual Tree Crowns in Airborne Lidar Data. *Photogrammetric Engineering & Remote Sensing*, 72, pp. 357–363.
10. Korpela I. (2006) Incorporation of Allometry into Single-tree Remote Sensing with LIDAR and Multiple Areal Images. Department of Forest Resource Management. University of Helsinki, Finland. p. 6.
11. Korpela I., Dahlin B., Schäfer H. (2007) Single-tree forest inventory using LIDAR and areal images for 3D treetop positioning, species recognition, height and crown width estimation. Department of Forest Resource Management. University of Helsinki, Finland. Available at: http://www.isprs.org/proceedings/XXXVI/3-W52/final_papers/Korpela_2007.pdf, 16 January 2009.
12. Korpela I., Tokola T., Ørka H.O., Koskinen M. (2004) Small – Footprint Discrete – Return LiDAR in Tree Species Recognition. Environmental Sciences, 387, pp. 1381–1386.
13. Korpela I., Tokola T.E. (2006) Potential of Aerial Image-Based Monoscopic and Multiview Single-Tree Forest Inventory: A Simulation Approach. *Forest Science*, 52, pp. 136–147.
14. Onge B., Jumelet J., Cobello M. (2004) Measuring Individual Tree Height Using a Combination of Stereophotogrammetry and Lidar. *Canadian Jornal of Forest Research*, 34, pp. 22–30.
15. Pitkänen J. (2001) Individual tree detection in digital aerial images by combining locally adaptive binarization and local maxima methods. *Canadian Journal of Forest Research*, 31, pp. 832–844.
16. Pitkänen J., Maltamo M., Hyyppäb J., Yub X. (2004) Adaptive Methods for Individual Tree Detection on Airborne Laser Based Canopy Height Model. *International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences*, 36 – 8/W2, pp. 187–191.
17. Popescu S.C., Wynne R.H., Nelson R.F. (2002) Estimating plot-level tree heights with lidar: local filtering with a canopy-height based variable window size. *Computers and Electronics in Agriculture*, 37, pp. 71–95.
18. Pouliot D., King D. (2005) Approaches for optimal automated individual tree crown detection in regenerating coniferous forests. *Canadian Journal of Remote Sensing*, 31, pp. 255–267.
19. Rahman M.Z.A., Gorte B. (2008) Individual Tree Detection Based on Densities of Height Points of Height Resolution Airborne LiDAR. Available at: http://www.isprs.org/proceedings/XXXVIII/4-C1/Sessions/Session12/6790_Rahman_Proc.pdf, 4 January 2012.
20. Rombouts J. (2006) Application of airbone LIDAR in forestry in North America and Scandinavia. The National Educational Trust of the Australian Forest Products Industries Fund. Australia. 2006. Available at: http://www.gottsteintrust.org/media/jrombouts.pdf, 16 January 2009.
21. Secord J., Zakhor A. (2006) Tree Detection in Aerial LiDAR and Image Data. Available at: http://www-video.eecs.berkeley.edu/papers/JSecord/ICIP2006_secord.pdf, 4 January 2012.
22. Tokola T., Vauhkonen J., Leppänen V., Pusa T., Mehtätalo L., Pitkänen J. (2008) Applied 3D Texture Features in ALS – Based Tree Species Segmentation. Available at: http://www.isprs.org/proceedings/XXXVIII/4-C1/Sessions/Session12/6724_Tokola_Proc.pdf, 4 January 2012.
23. Vauhkonen J., Tokola T., Leppänen V. (2008) Applied 3D texture features in ALS-based tree species segmentation. University of Joensuu, Faculty of Forest Sciences. Available at: http://homepages.ucalgary.ca/~gjhay/geobia/Proceedings/Sessions/Session12/6724_Tokola_Proc.pdf, 16 January 2009.
24. Weinacker H., Koch B., Heyder U., Weinacker R. (2004) Development of filtering, segmentation and modeling modules for LiDAR and multispectral data as a fundament of an automatic forest inventory system. *ISPRS: Laser-scanners for forest and landscape assessment*, 34-8/W2, pp. 50–55.

LITTER INVERTEBRATE COMMUNITIES IN PINE FORESTS OF DIFFERENT AGE (BARANIVKA AREA, UKRAINE)

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Abstract
Litter invertebrate communities in pine forests of different age (cut, six-year-old, 45-, 62-, and 105-year-old) in the Baranivka area of Zhytomyr Polissya (northwestern part of Ukraine) were studied. Samples were collected in April, August, and November 2011. 99% of extracted invertebrates were represented by mites (Acari) and springtails (Collembola). With forest age, the following tendencies were observed: mean absolute density of mites, springtails, and all litter-inhabiting animals increased; relative abundance of mites increased, but relative abundance of springtails decreased; taxonomic richness of invertebrate communities increased. In all samples, the most represented taxon was suborder Oribatida. The most diverse litter invertebrate community was in the 45-year-old forest. Similar compositions of invertebrate community were in the 45-, 62-, and 105-year-old forests as well as the cut and six-year-old ones.
Key words: pine forest, litter invertebrates, Acari, Collembola, density, similarity.

Introduction

Forest litter plays an important role in the forest ecosystem. It influences chemical composition of a solution that enters the soil, regulates heat regime and water-physical characteristics of the forest soil. A litter contains organic matters at different stages of their decomposition and humification. The quantity of forest litter depends on the species composition, age, shape and type of stands, soil water regime, live soil cover, and other factors. Soil-inhabiting fauna coupled with soil microflora, contribute to the soil quality. They are associated with the decomposition and transformation of dead organic substances into inorganic ones (Curry, 1973; Knoepp et al., 2000; Seastedt, 1984; Tripathi et al., 2005; Wang et al., 2009). Conventional forest harvesting practices has a negative impact on these processes leading to the changes of the distribution, composition, and activity of the soil biological communities (Marshall, 2000). Many studies consider soil microarthropods as possible indicators of soil quality (Knoepp et al., 2000, Lindo, Visser, 2004).

In Ukraine, studies on structural organization of litter invertebrates were conducted in steppe forests (Бригадиренко, 2007; Кульбачко, 1999). The objective of our work was to study litter-dwelling invertebrates in pine forests of Zhytomyr Polissya, especially quantitative and qualitative characteristics of their communities depending on the forest age.

Materials and Methods

The study was conducted in the Baranivka area of Zhytomyr Polissya. The area is located at the latitude of 50°18´ north and the longitude of 27°40´ east within the altitude of 156 m above the sea level in the northwestern part of Ukraine. The climate in this area is mild continental with warm and humid summer with a mean temperature in July +18.9 °C and mild winter with a mean temperature in January –5.7 °C. The total annual precipitation is 600 mm. The level of underground water is 2.5 to 3.5 m.

Litter was sampled at the beginning of April, August, and November 2011 in the fresh pine forests of the following age groups (abbreviated denotation is given in brackets): 1) cut, the 90-year-old forest was cut in December 2010; 2) non-closed forest, 6 years old (F 6); 3) young forest, 45 years old (F 45); 4) middle-aged forest, 62 years old (F 62) and 5) mature forest, 105 years old (F 105).

A sample was a square litter monolith sized 10 x 10 cm each (100 cm^2) with the thickness of a monolith equaled the thickness of the litter: in the cut forest – 1-2 cm, six-year-old – 0.5-1 cm, 45-year-old – 3 cm, 62-year-old – 3-4 cm, and 105-year-old – 3-5 cm**.** A total of 75 samples were examined (5 treatments x 5 sampling occasions x 3 seasons). Invertebrate extraction was conducted using modified Tullgren funnels (diameter 15 cm) containing inserted wire mesh with cells 2x2 mm. As a source of heat electrical bulb was used. Invertebrates dropped through the exit hole of the funnel into collecting bottles containing 70% alcohol. Extraction time lasted two days. The total numbers of individuals in major groups were calculated with dissecting microscope at 40x magnification. Mites were classified to suborders and/or families using compound microscope at 100x magnification.

To characterize the composition of invertebrate communities and their diversity, the following ecological indices were used: density, percentage relative abundance, a comparison of two samples with Student's t-test, Shannon's index of biodiversity, inverse of Simpson's index, and index of similarity after Marczewski and Steinhaus.

The relative abundance (percentage of total) of microarthropod suborders was calculated using the formula: number of individuals in a suborder / total number of individuals x 100 (1).

The Shannon's index of biodiversity (*H'*) was calculated using the formula: $H' = - \Sigma (p_i \ln p_i)$ (2), where *H'* is Shannon's index; p_i is the relative abundance of each species, calculates as the proportion of individuals of a given species (n_i) to the total number of individuals in the community (*N*): *ni/N* (Magurran, 2004).

The diversity index, inverse of Simpson's, was calculated using the formula: $1/D = 1/\Sigma p_i^2$ (3), where *D* is Simpson's index and p_i is the proportion of individuals of a given species (Magurran, 2004).

Marczewski and Steinhaus index of similarity (MS) was calculated using the formula: $s=c/(a+b-c)$ (4), where *s* is a similarity of two compared communities, *a* – the number of taxa in community A, *b* – the number of taxa in community B, and c – the number of taxa common for A and B (Magurran, 2004).

Results and Discussion

In all litter samples, invertebrate communities were composed predominantly of mites (Acari) and springtails (Collembola), the representatives of miroarthropods, which accounted for up to 99% of extracted animals (Table 1, Fig.1). Our data are consistent with findings of other authors who pointed out that these two groups of microarthropods are prevalent components of soil-litter fauna (Lindo and Visser, 2003; Wang et al., 2009). According to literature, they are responsible for the decomposition process, and their abundance directly correlates with the litter mass loss rates (Seastedt, 1984; Tripathi et al., 2005; Wang et al., 2009). Among other extracted invertebrates were representatives of the following taxa: Aranae, Pseudoscorpionida, Annelida, Nematode, Centipedes, Coleoptera, Hymenoptera, and insects larvae.

The annual mean density of all extracted animals differed considerably depending on the forest age: the highest number, 66,320 ind m^{-2}, was observed in the 105- year-old forest but the lowest, 6,500 ind m^{-2}, – in the six-year-old one. In the cut and six-year-old forest, the density of invertebrate community was the lowest. Comparing these two forests, there was a slight decline in the quantity of all animals and mites in the six-year-old forest (Table 1). This effect is probably related to changes in the litter quantity and quality and, as a result, to negative impact of the environment on the soil properties and available food resources. According to Marshall (2000), and Lindo, Visser (2004) harvesting leads to the reduction and redistribution of the matter, compaction, changes in plant cover, and modification of microclimate and directly affects microarthropod communities.

Starting from six-year-old forest, the total number of animals in the litter increased with the age of forest (Table 1, Fig. 1). The most significant growth in animals' abundance was in the 45-year-old forest compared to the six-year-old when the density of all arthropods increased more than 7.5 times, mites – 8.6, and springtails – 5.2 times. The relative abundance of Acari ranged from 70 to 82% of all extracted animals. Their annual mean density varied from 4,520 ind m^{-2} in the six-year-old forest to 53,707 ind m^{-2} in the 62-year-old forest.

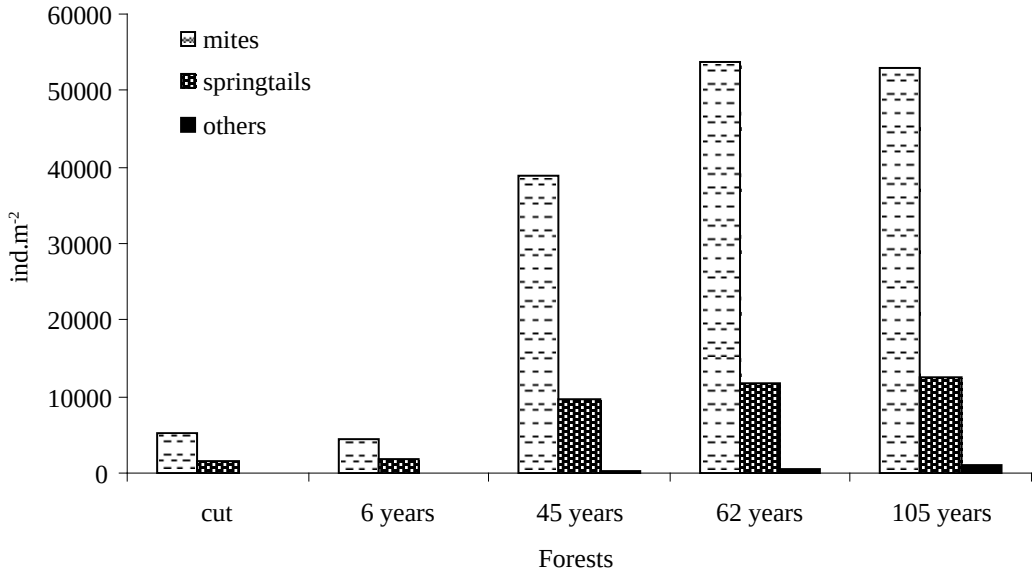

Figure 1. Annual mean density of mites, springtails and other invertebrates in the litter of pine forests of different age.

Table 1

Composition and annual mean density of litter invertebrates in the pine forests (F) of different age (years)

Taxa	Cut		F (6)		F (45)		F (62)		F (105)	
	ind m^{-2}	%	ind m^{-2}	%	ind m^{-2}	%	ind m^{-2}	%	ind m^{-2}	%
Acari:										
Prostigmata (total)	1,667	24	1,094	17	11,847	24	25,586	24	13,974	21
Eupodidae	213	3	127	2	1,740	4	2,113	3	1,893	3
Tydeidae	93	1	100	2	1,127	2	2,013	3	1,827	3
Bdellidae	140	2	93	1	1,467	3	1,873	3	1,727	3
Rhagidiidae	73	1			640	1	860	1	640	1
Cunaxidae					260	< 1	260	< 1	187	< 1
Pseudocheylidae	40	< 1	7	< 1			200	< 1	213	< 1
Paratydeidae					93	< 1	127	< 1		
Scutacaridae					107	< 1	373	< 1	1,020	2
Other Prostigmata	1,107	16	767	12	6,413	13	7,767	12	6,467	10
Mesostigmata (total)	173	2	127	2	2,574	5	2,240	3	3,466	5
Phytoseiidae					560	1	500	< 1	893	1
Rhodacaridae					847	2	560	< 1	1,013	2
other Gamasides	173	2	127	2	1,167	2	1,180	2	1,560	2
Oribatida	3,187	46	2,847	44	22,320	46	33,880	51	33,320	50
Astigmata	173	2	453	7	2,067	4	2,000	3	2,193	3
Total Acari	5,200	75	4,520	70	38,807	79	53,707	82	52,953	80
Collembola										
Collembola	1,640	24	1,887	29	9,753	20	11,693	18	12,420	19
Other invertebrates:										
Insects larvae	60	< 1			93	< 1	113	< 1	713	1
Coleoptera					7	< 1	213	< 1	7	< 1
Hymenoptera									20	< 1
Centipedes					13	< 1	13	< 1	47	< 1
Other insects			13	< 1	40	< 1	107	< 1	120	< 1
Areneae			13	< 1					13	< 1
Pseudoscorpionida									20	< 1
Nematode					140		67	< 1	7	< 1
Annelida			67	1			7	< 1		
Total	60	< 1	93	1	293	1	520	1	947	1
All invertebrates	6,900		6,500		48,853		65,920		66,320	
N of taxa	11		12		19		22		23	
H' index	1.54		1.44		1.74		1.66		1.72	
1/*D* index	3.35		3.38		3.68		3.19		3.31	

Mite population in all studied samples included Oribatid, Prostigmatid, Mesostigmatid, and Astigmatid mites. The relative contribution of these suborders to the total mite abundance changed slightly with forest age (Fig. 2). The main contributors to the mite population were Oribatid and Prostigmatid mites which accounted for 87 to 93% of mite populations. Suborder Oribatida was the most numerous in forests of all ages. It constituted from 58 to 63 % of all mites (Fig. 2). Oribatida mites also dominated among all extracted animals. Their relative abundance ranged from 44 to 51% (in the six-year-old and 62-year-old forests respectively) of all invertebrates in the litter (Table 1). Many studies reported Oribatid mites as the most frequently found animals of a soil mesofauna community (Lindo and Visser, 2004; Silvan et al., 2000; Wallwork, 1983; Wang et al., 2009). The trophic activities of Oribatids, namely the consumption of fungal biomass and comminution of dead plant materials, result in fecal pellets, which enlarge surface area for primary decomposition by bacteria and fungi and contribute to soil microstructure (Pawluk, 1985).

Prostigmata mites were the second most abundant suborder of mites. They accounted for 17% of all animals in the six-year-old forest and from 21 to 24% in other age groups (Table 1). Their contribution to mite abundance was from 24 to 32% (Fig. 2). Representatives of eight families of Prostigmatid mites, namely Eupodidae, Tydeidae, Bdellidae, Rhagidiidae, Cunaxidae, Pseudocheylidae, Paratydeidae, and Scutacaridae were identified. Three of them, Cunaxidae, Paratydeidae, and Scutacaridae, were not present in the cut forest. The six-year-old forest lacked the same families like the cut forest, and Rhagidiidae. Mesostigmatid mites constituted from 2% in cut and F (6) to 5% in F (45) and F (105) of all extracted invertebrates (3-7% of all mites). Two families of Mesostigmatid mites, Phytoseiidae and Rhodacaridae, were identified in the forests starting from 45 years old and older (Table 1). Many of Prostigmatid and almost all of Mesostigmatid mites are predators; however, some species are fungal feeders (Christine et al., 2001). Cohort Astigmata accounted for 2 to 7% of all invertebrates in samples (3-10% of all mites). Their highest relative abundance was in the six-year-old forest. With forest age, their quantity diminished. According to qualitative characteristics of mite community, the richest was 62-year-old forest followed by 105- and 45-year-old forests; the poorest was six-year-old one.

Springtails constituted 18% in F (62) to 29% in F (6) of all invertebrates in the litter. Their lowest density, 1,640 ind m^{-2}, was observed in the cut forest (Table 1, Fig.1). With forest aging, their density increased and reached the highest value (12,420 ind m^{-2}) in the 105-year-old forest. The relative contribution of springtails was inversely proportional to the mite's one: relative density decreased from six-year-old to 62-year-old forest. The literature suggests that abundance of both, Acari and Collembola correlates positively with microbial and fine-root biomass (Kandeler, 1999; Lindo and Visser, 2003; Marshall, 2000). Other invertebrates in the litter gradually increased in numbers from 60 ind m^{-2} in the cut forest to 947 ind m^{-2} in the mature forest (Table 1). Their contribution to the litter invertebrate population was stable (around 1%) in forests of all examined ages.

Taxonomic richness of invertebrate communities increased with the age of forest. The least number of taxa (11) was found in the cut forest and the greatest number (23) – in the 105-year-old one (Table 1). The Shannon's index of diversity (*H'*) ranged from 1.44 in the six-year-old to 1.74 in the 45-year-old forest. According to this index, studied forests can be arranged in the following order (from highest value of index to smallest): F (45) – F (105) – F (62) – cut – F (6).

The inverse Simpson's index of diversity (1/*D*) was highest in the 45-year-old forest (3.68) and the lowest (3.19) in the 62-year-old one (Table 1). According to this index, studies forests are arranged in the following order (from highest to lowest value): F (45) – F (6) – cut – F (105) – F (62).

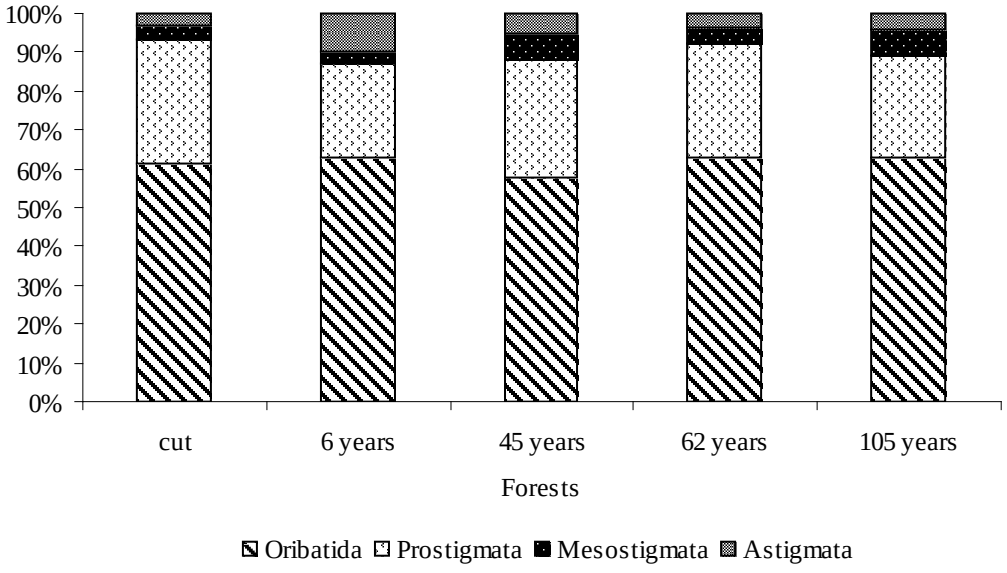

Figure 2. Percentage contribution of mite suborders to the total numbers of mites in pine forests of different age.

Table 2

Index of similarity after Marczewski and Steinhous in forests (F) of different age (years): a – for all invertebrates, b – for mites

	Cut		F (6)		F (45)		F (62)	
	a	b	a	b	a	b	a	b
F (6)	0.64	0.89						
F (45)	0.5	0.57	0.41	0.5				
F (62)	0.52	0.64	0.5	0.57	0.91	0.93		
F (105)	0.5	0.69	0.48	0.62	0.78	0.86	0.79	0.93

he index of similarity after Marczewski and Steinhous (MS) indicates that 45-, 62-, and 105-year-old forests have similar invertebrate community composition (Table 2, a). The most similar communities (MS = 0.91) were in forests of 45 and 62 years old. The least similar (most different) communities were in the six-year-old forest and 45-year-old one (MS = 0.41). Low MS index was also between six-year-old forest and 62- and 105-year-old ones as well as between cut forest and forests of 45 years old and older.

For mites, highly similar community structure was observed in 45-year-old forest and older (MS index ranged from 0.86 to 0.93) and in the cut and the youngest forest (MS = 0.89). The less similar and more diverse mite population was in the following pairs of forests: six-year-old and 45-year-old (MS = 0.5), six-year-old and 62-year-old (MS = 0.57) and cut and 45-year-old (MS = 0.57) (Table 2, b).

Statistical analysis of invertebrate densities between pairs of forests shows that differences vary from highly significant to non-significant (Table 3). It is highly significant between the following pairs: cut and young forest, cut and middle-aged, cut and mature forest as well as between non-closed and any other age group for total number of individuals, mites, and springtails. There were no significant differences between six-year-old and cut forests, 45- and 62-year-old, 45- and 105-year-old, and 62- and 105-year-old forests.

The density of all litter-inhabiting mesofauna and its major groups in pine forests varies significantly during the year (Fig. 3). In the cut and six-year-old forests, the lowest density was observed in summer. The highest number of animals in the former forest was in spring but in the latter – in fall. In the 45-year-old forest and older, the most inhabited litter was in summer. In these forests, the differences between summer and fall invertebrate abundance were statistically significant ($p<0.05$). The lowest abundance in the 45- and 62-year-old forests was in fall, and in the 105-year-old – in spring. Spring to summer comparison of invertebrate abundance in the oldest forest was statistically significant ($p<0.01$).

Significant seasonal variations were also observed in mites' abundance (Fig. 3). In all forests, except six-year-old one, the lowest absolute density of mites was in fall. In 45- and 105-year-old forests, the highest mites density was observed in summer whereas in the cut and 62-year-old one – in spring. Statistically significant differences in mean values of mite density in spring, summer, and fall were in the cut forest ($p<0.05$). Summer and fall mite abundance differed in 45-, 62-, and 105-year-old forests ($p<0.05$); spring and summer abundance was also statistically different in the oldest forest ($p<0.01$).

The highest abundance of collembolan species in the cut, 62-, and 105-year-old forests was in summer, in six-year-old – in fall, whereas in the 45-year-old – in spring. However, there were no significant differences in their abundance in all forests except F (45) between spring and fall communities ($p<0.05$). Literature analysis indicates that seasonal peaks of soil mesofauna abundance, especially Collembola, depend on the weather conditions (Pernin et al., 2006). Collembola are more sensitive to desiccation than mites, which are covered with cuticle. We cannot draw

Table 3

Statistical significance of the differences of mean values of litter invertebrate densities in forests (F) of different age (years) between pairs of sites: a –invertebrates (total); b – mites; c– springtails (*P<0.001, **** P≤0.0001, n.s. – nonsignificant)**

	Cut	F (6)	F (45)	F (62)
F (6)	a, b, c – n.s.			
F (45)	a****, b****, c****	a***, b****, c***		
F (62)	a****, b****, c***	a****, b****, c***	a, b, c – n.s.	
F (105)	a***, b***, c****	a****, b***, c****	a, b, c – n.s.	a, b, c – n.s.

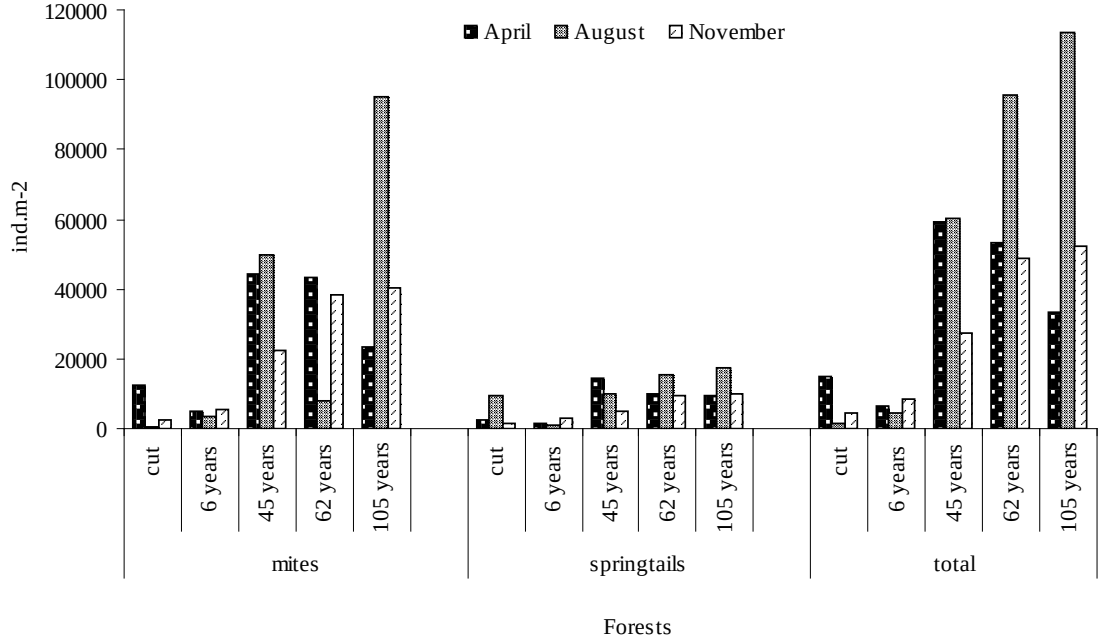

Figure 3. Density dynamics of mites, springtails, and total invertebrates in forests of different age during the year.

any definite conclusions on the seasonal fluctuations in the litter mesofauna abundance observed in our study yet, as it requires additional observations.

Conclusions

1. In all studied forests, 99% of extracted invertebrates were represented by Acari and Collembola. Mean absolute density of litter-inhabiting animals increased with the age of forest. The most significant growth of mite's, springtails, and total animal's abundance was observed in the 45-year-old forest compared to six-year-old one.
2. The contribution of Acari to litter communities ranged from 70 to 82%. Their absolute and relative density increased with forest aging. Oribatid mites dominated in forests of all ages and accounted from 44 to 51% in all extracted animals.
3. Collembola amounted 18 to 29% of the litter-dwelling invertebrates. With forest age, their absolute density increased but their relative contribution decreased.
4. Taxonomic richness of invertebrate communities increased with forest aging. The least number of taxa (11) was found in the cut forest and the greatest number (23) – in the 105-year-old one. According to Shannon's (*H'*), and inverse Simpson's (1/*D*) indices of diversity, the 45-year-old forest had the most diverse litter invertebrate community.
5. Index of similarity after Marczewski and Steinhous (MS) indicated that the 45-, 62-, and 105-year-old forests as well as the cut and six-year-old ones had the most similar composition of invertebrate community.
6. Mite's, springtails and total invertebrate abundance were subject to considerable seasonal variations.

References

1. Christine G.N., Robert P., Torolf R.T. (2001) Soil, litter, and coarse woody debris habitats for arthropods in eastern Oregon and Washington. *Nothwest Science*, 75, pp. 141–148.
2. Curry J.P. (1973) The arthropods associated with the decomposition of some common grass and weed species in the soil. *Soil Biology and Biochemistry.* 5, pp. 645–657.
3. Kandeler E., Kampichler C., Joergersen R.G., Motler K. (1999) Effects of mesofauna in a spruce forest on soil microbial communities and N cycling in field mesocosms. *Soil Biology and Biochemistry*, 31. pp. 1783–1792.
4. Knoepp D.J., Coleman D.C., Grossley Jr D.A., Clark J.S. (2000) Biological indices of soil quality: an ecosystem case study of their use. *Forest Ecology and Management.* 138. pp. 357–368.
5. Lindo Z., Visser S. (2003) Microbial biomass, nitrogen and phosphorus mineralization, and mesofuna in boreal conifer and deciduous forest floors following partial and clear-cut harvesting. *Canadain Journal of Forestry Research*, 33, pp. 1610–1020.

6. Lindo Z., Visser S. (2004) Forest floor microarthropod abundance and oribatid mite (Acari: Oribatida) composition following partial and clear-cut harvesting in the mixed boreal forest. *Canadian Journal of Forestry Research*, 34, pp. 998–1006.
7. Magurran A.E. (2004) Measuring biological diversity. Blackwell Publishing. Malden, MA. 256 p.
8. Marshall V.G. (2000) Impacts of forest harvesting on biological processes in northern forest soils. *Forest Ecology and Management*, 133, pp. 43–60.
9. Pawluk S. (1985) Soil micromorphology and soil fauna: problems and importance. *Quaestiones Entomologicae*, 21, pp. 473 – 496.
10. Pernin C., Cortet G., Joffre R., Petit J.L., Torre F. (2006) Sewage sludge effects on mesofauna and cork oak (*Quercus suber* L.) leaves decomposition in a Mediterranean firebreak. *Journal of Environmental Quality*, 35, pp. 2283–2292.
11. Seastedt T.R. (1984) The role of microarthropods in the decomposition and mineralization of N. *Annual Review of Ecology and Systematics*, 29, pp. 25–46.
12. Silvan N., Laiho R., Vasander H. (2000) Changes in mesofauna abundance in peat soils drained for forestry. *Forest Ecology and Management*, 133, pp. 127–133.
13. Tripathi G., Kumari R., Sharma B.M. (2005) Association of soil mesofauna with litter decomposition. *Cientifica, Jaboticabal*, 33, pp. 148–151.
14. Wallwork J.A. (1983) Oribatids in forest ecosystems. *Annual Review of Entomology*, 28, pp. 109–130.
15. Wang S., Ruan H., Wang B. (2009) Effects of soil microarthropods on plant litter decomposition across an elevation gradient in the Wuyi Mountains. *Soil Biology and Biochemistry*, 41, pp. 891–897.
16. Бригадиренко В.В. (2007) Екологічні особливості формування комплексів підстилкових безхребетних лісових біогеоценозів (Ecological patterns of forming litter invertebrate fauna in forest ecosystems of steppe zone of Ukraine). Abstract of thesis for a doctor's degree of biological sciences by speciality 03.00.16 – ecology. Dnipropetrovsk National University, Dnipropetrovsk, 39 c. (in Ukrainian).
17. Кульбачко Ю.Л. (1999) Стан структурної організації безхребетних тварин підстилки степових лісів в умовах промислового забруднення (The state of structural organization of invertebrates in a litter of steppe forests under conditions of industrial pollution). Abstract of PhD theses (biology). Dniepropetrovsk State University, Dniepropetrovsk, 21 c. (in Ukrainian).

HETEROBASIDION SPP. IN *PICEA ABIES* UNDERSTORY: INCIDENCE AND IMPACT ON RADIAL GROWTH OF TREES

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Abstract
Heterobasidion spp. is an important pathogen in the Northern Hemisphere, causing root and butt rot mainly in conifers. Norway spruce (*Picea abies* (L.) Karst.) is one of the most common tree species infected by *Heterobasidion* spp. In Latvia, 22.9% of Norway spruce stumps are infected. *Heterobasidion* spp. decreases timber quality, but what impact it has on Norway spruce growing in understory of dominant stand is not known. The aim of the study was to evaluate incidence of *Heterobasidion* spp. on understory Norway spruce in *Myrtillosa* forest type and impact on radial growth of trees. In autumn of the year 2011 in a sample plot located in forests of Kalsnava district a total number of 258 trees were examined for presence of *Heterobasidion* spp. Results showed that 54% of examined trees were rotted. In 30% of trees *Heterobasidion* spp. was detected. It is concluded that *Heterobasidion* spp. does not impact radial growth on understory Norway spruce trees.
Key words: *Picea abies*, understory, radial growth, *Myrtillosa*, *Heterobasidion*.

Introduction

Heterobasidion spp. is an important pathogen in the Northern Hemisphere (Bendz-Hellgren and Stenlid, 1997), causing root and butt rot in many tree species, mainly conifers (Asiegbu et al., 2005). It is estimated that in Europe total economic losses caused by *Heterobasidion* spp. exceed 500 million euros annually. Mainly loses can be attributed to loss of timber quality (*Heterobasidion annosum: biology…*, 1998).

According to the study of A. Василяускас (1989), in Lithuania depending from age, 20% – 58% of Norway spruce (*Picea abies* (L.) Karst.) trees in drained forest stands are infected with *Heterobasidion* spp., but in Finland approximately 17% - 30% of Norway spruce trees are infected with *Heterobasidion* spp. (Tamminen, 1985). In Latvia on average 22.9% (Gaitnieks et al., 2007) of Norway spruce stumps are infected.

Studies in Sweden show that heavily decayed Norway spruce trees in dominant stands, planted between 1961 – 1962, have lost 9% of their diameter growth at breast height during 5 year period (Bendz-Hellgren and Stenlid, 1997). There is a lack of studies about *Heterobasidion* spp. incidence in understory Norway spruce. Finnish studies show that in 14 - 44 years old advanced growth Norway spruce stands *Heterobasidion* spp. average incidence is 52.5% (Piri and Korhonen, 2001).

The aim of this study is to evaluate incidence, decay column in stem and impact of *Heterobasidion* spp. on radial growth of Norway spruce trees growing in the understory of Scots pine (*Pinus sylvestris* (L.)) stand in *Myrtillosa* forest type.

Materials and Methods

Materials for this study were taken in autumn of the year 2011, from a stand managed by 'State Forest Service – Forest Research Station'. The stand is located in Eastern part of Latvia, Kalsnava district with a total area of 6.0 ha and sample plot area 0.6 ha (60×100 m). During this study a total of 258 randomly selected Norway spruce trees were evaluated. Trees were taken from understory of 113 years old Scots pine stand in *Myrtillosa* forest type.

Selected trees were numbered and felled to detect the presence of rot and for height measurements with accuracy to one centimetre. For trees with the presence of *Heterobasidion* spp. stump diameters with bark and without bark were measured with digital sliding calliper (accuracy 0.1 mm). To ascertain spread of *Heterobasidion* spp., the diameter of rot on each stump was measured (accuracy 0.1 mm) and 2 – 3 cm thick sample disc was sawed for further analysis in the laboratory to confirm the actual presence of *Heterobasidion* spp. infection (138 totally).

Afterwards 107 (76 infected, 31 not infected) out of 258 felled trees were crosscut at breast height (1.3 m from root collar) to collect sample discs for further diameter at breast height and radial growth measurements. Top part of infected trees was split in several pieces to detect the maximum height of decay column (measured with accuracy to one cm).

In the laboratory 138 sample discs from stumps were examined for the presence of *Heterobasidion* spp. conidiophores (Swedjemark, 1995). Laboratory tests confirmed that 76 trees were infected by *Heterobasidion* spp. but on 62 sample discs no conidiophores appeared.

For further data extraction 107 (76 infected, 31 not infected) sample discs from breast height were polished and scanned using 'Epson Perfection 4990 PHOTO' scanner with resolution 2,540 points per inch, height and width of one pixel 0.01 mm, and stored as colour JPEG images.

Scanned JPEG images were examined for damages and growth anomaly's that could affect the quality of data. After sorting, 60 images (32 infected sample discs and 28 not infected sample discs) were imported in AutoCAD 2012 software for further measurements with ratio one pixel is one point. At first, central coordinates (0:0) were set up for all samples in the centre of the first growth ring and through it perpendicular leading diagonals so that one represents the tallest diameter of the sample disc were drawn.

Measurements for rot diameter at breast height from infected sample discs as a length of 4 perpendicular radii (accuracy to 0.01 mm) from the centre using diagonals set earlier as a direction were taken. Collected data were exported to MS Excel datasheets. Exported information contained the length of radii. To get an average *Heterobasidion* spp. diameter at breast height for each infected tree, all 4 radii were summed and divided by 2. Final data were rounded to 0.1 mm.

Measurements of radii for calculation of diameter with and without bark and diameter at breast height at the beginning of year 2001 (D_1) and beginning of the year 2011 (D_2) (reference period 10 full growth seasons) at breast height for all trees were measured as described previously for rot diameter at breast height measurements. Collaterally to data previously described, number of growth rings at breast height was counted for each tree. For further necessity difference (ΔD) between D_2 and D_1 was calculated, to determine increment during the reference period.

After gathering all information, descriptive statistics for D_1, height and age, were calculated for each group using MS Excel function 'Descriptive statistics' to check whether both groups have identical mean values and the stand has had an identical growth conditions till the beginning of evaluation period.

To compare mean values, descriptive statistics were calculated for ΔD for each group separately,. Variance analysis was carried out between both groups of D_1 and ΔD to see the significance of *Heterobasidion* spp. impact on growth of understory Norway spruce trees during reference period.

To find out the spread of *Heterobasidion* spp. in infected stems, comparative calculations of decay column height against full tree height was calculated. For the same reason *Heterobasidion* spp. diameter against tree diameter without bark at stump height and breast height were calculated. Comparison between *Heterobasidion* spp. diameter at stump height and length of decay column in stem were calculated and tested for correlation using software 'IBM SPSS statistics 20'.

Results and Discussion

Incidence of *Heterobasidion* spp. in Norway spruce trees growing in understory of Scots pine stand in *Myrtillosa* forest type is approved because rot damages were found on 138 (54%) out of 258 understory Norway spruce trees selected. In the laboratory presence of *Heterobasidion annosum* s.l. was approved for 76 (30%) out of 258 understory Norway spruce trees selected. Age at breast height of the trees examined for this study was from 21 to 42 years (average 34.5±0.7).

Results acquired from 32 infected and 28 healthy trees used for further analysis showed that at the beginning of the year 2001 difference of mean diameter (5.72±0.25 cm) values for infected and mean diameter (5.87±0.25 cm) values for healthy trees are not significant ($p=0.67>0.05$), and it approves that the stand has had a similar growing conditions for trees from both groups, and data can be used for further calculations.

Table 1

Summary of sample tree characteristics

Parameter	D_1, cm*		ΔD, cm**		Age, years***	
	healthy	infected	healthy	infected	healthy	infected
Mean	5.72	5.87	0.90	0.84	34.0	34.9
Standard error	0.25	0.25	0.06	0.05	1.0	0.9
Sample Variance	1.72	1.99	0.12	0.08	29.6	25.6
Range	4.93	5.49	1.41	1.25	19.0	19.0
Minimum	2.72	3.01	0.47	0.34	23.0	21.0
Maximum	7.65	8.50	1.87	1.60	42.0	40.0

* Diameter at breast height at the beginning of 2001
** Increment during reference period (10 years)
*** Age of trees at breast height in 2011

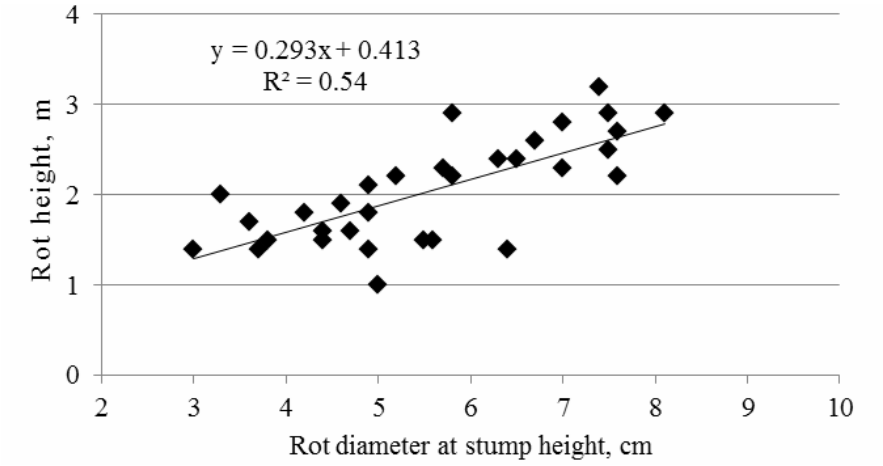

Figure 1. *Heterobasidion* spp. spread in stem ($p<0.01$).

Results for ΔD showed that during reference period, the difference between groups has not changed and is not significant ($p=0.47>0.05$); mean ΔD (0.90±0.07 cm) infected, mean ΔD (0.85±0.06 cm) healthy (Table 1). The difference cannot be seen significant ($p=0.60>0.05$) also between mean heights of trees from both groups measured at the end of the year 2011; mean height (8.0±0.4 m) healthy, mean height (8.2±0.4 m) infected. According to Bendz-Hellgren and Stenlid (1997), Norway spruce trees infected with *Heterobasidion* spp. should show a decrease in annual growth during 5 years, but results acquired in this study shows that infection has not affected annual increment in last 10 years of Norway spruce trees growing in Scots pine stands understory.

Results on spread of *Heterobasidion* spp. in Norway spruce stem shows that the average diameter of *Heterobasidion* spp. at the stump height is 5.6±0.25 cm or 77.1±1.6% from the total diameter without bark. Similar results show *Heterobasidion* spp. spread diameter at the breast height - 5.4±0.32 cm or 78.1±2.0% from the total diameter without bark. According to height, results show that the mean height for *Heterobasidion* spp. is 2.03±0.1 m, or 25.6±1.08% from the total mean height of infected trees. Decay caused by *Heterobasidion* spp. in the stem of Norway spruce can spread up to 8-11 m height in middle aged stands (Stenlid and Wasterlund, 1986). *Heterobasidion* spp. ratio between diameter of rot at stump height and rot height is 1:37.4±1.4 and has a significantly medium-tight linear correlation between parameters ($r=0.74$, $r_{0.01;\,32}=0.452$, $n=30$) (Figure 1).

Results of study mentioned by R. Vasiliauskas and J. Stenlid (1998) show that spread of *Heterobasidion* spp. extends to a height about 20-22 times its diameter at stump height. The difference in results could be explained with fact that trees examined in R. Vasiliauskas and J. Stenlids study were 60 years old but ours (35.5 years) almost a half of that age and it could mean that spread of *Heterobasidion* spp. in height slows down in older trees.

It is discovered that for higher data credibility, in further studies of understory Norway spruce trees, spread of root rot in stems (felled for full analysis) should be measured as area. In further studies the impact of *Heterobasidion* spp. on increment of understory Norway spruce will be analysed in other forest types. This study is made on data obtained from 1 sample plot; therefore, results described are considerable as preliminary.

Conclusions

1. Frequency of root rot in analysed understory Norway spruce sample plot in *Myrtillosa* forest type is 54% (30% of trees were infected with *Heterobasidion* spp).
2. In this study the analysis of increment for last 10 years of understory Norway spruce trees in *Myrtillosa* forest type, show that there is no increment difference between trees infected with *Heterobasidion* spp. and healthy ones.
3. Decay column of *Heterobasidion* spp in the analysed understory Norway spruce trees, exceeds its diameter at stump height 37.4 times.

References

1. Asiegbu F.O., Adomas A., Stenlid J. (2005) Conifer root and butt rot caused by *Heterobasidion annosum* (Fr.) Bref. *s.l. Molecular Plant Pathology*, 6, pp. 395–409.
2. Bendz-Hellgren M., Stenlid J. (1997) Decreased volume growth of *Picea abies* in response to *Heterobasidion annosum* infection. *Canadian Journal of Forest Research*, 27, pp. 1519–1524.

3. Gaitnieks T., Arhipova N., Donis J., Stenlid J., Vasaitis R. (2007) Butt rot incidence and related losses in Latvian *Picea abies* (L.) Karst stands. In: Garbelotto M. and Gonthier P. (eds) Root and Butt Rots of Forest Trees. *Proceedings of the 12 th IUFRO International Conference on Root and Butt Rots,* The University of California, Berkeley, California, Medford, Oregon, USA, pp. 177–179.
4. *Heterobasidion annosum: biology, ecology, impact and control*. (1998) Woodward S., Stenlid J., Karjalainen R., Hüttermann A. (eds.), CAB International, Wallingford, UK, 589 pp.
5. Piri T., Korhonen K. (2001) Infection of advance regeneration of Norway spruce by *Heterobasidion parviporum*. *Canadian Journal of Forest Research*, 31, pp. 937–942.
6. Stenlid J., Wasterlund I. (1986) Estimating the frequency of stem rot in *Picea abies* using an increment borer. *Scandinavian Journal of Forest Research*, 1, pp. 303–308.
7. Swedjemark G. (1995) *Heterobasidion annosum root rot in Picea abies: variability in aggressiveness and resistance*, PhD thesis, Swedish University of Agricultural Sciences, Uppsala, Sweden, 42 pp.
8. Tamminen P. (1985) Butt rot in Norway spruce in Southern Finland, *Communicationes Instituti Forestalis Fenniae*, 127, pp. 1–52.
9. Vasiliauskas R., Stenlid J. (1998) Spread of S and P group isolates of *Heterobasidion annosum* within and among *Picea abies* trees in central Lithuania. *Canadian Journal of Forest Research*, 28, pp. 961–966.
10. Василяускас А. (1989) *Корневая губка и устойчивость экосистем хвойных лесов* (Root fungus and the resistance of coniferous forests' ecosystems), Vilnius Mokslas, Вильнюс, 175 с. (in Russian).

SOME PECULIARITIES OF LABORATORY MEASURED HYPERSPECTRAL REFLECTANCE CHARACTERISTICS OF SCOTS PINE AND NORWAY SPRUCE NEEDLES

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Abstract
The aim of the study was to investigate the properties of hyperspectral reflectance data of Scots pine (*Pinus Sylvestris L.*) and Norway spruce (*Picea Abies L.*). The hyperspectral reflectance data was obtained under laboratory conditions from the last season's needles of healthy 20 year-old trees from the same site. Hyperspectral data was acquired using Themis Vision Systems LLC VNIR 400H portable scanning hyperspectral imaging camera in 400-1000 nm range. Methods of analysis of variance, discriminant analysis and principal component analysis were applied for the hyperspectral data analysis. Differences between Scots pine and Norway spruce reflection data were examined. The most informative spectral range for Norway spruce – Scots pine spectral separation was determined at 666.5 nm – 668.4 nm, most informative waveband - 667.1 nm. Reflectance variations among individual trees of the same species as well as differences in spectral response between needles from northern – southern crown exposition were tested. A significant variation in spectral response of needles of Norway spruce was detected across the whole measured spectral range (955 wavebands) for each sample tree. However, significant variation of spectral response of needles of Scots pine was detected only in 356 out of 955 wavebands for each sample tree. Depending on the crown exposition to the North or South, the reflectance of Scots pine needles differed significantly in 900 spectral bands. No significant differences were detected in 833 wavebands for Norway spruce.
Key words: Imaging spectrometry, hyperspectral reflectance, waveband selection, coniferous.

Introduction

Hyperspectral remote sensing, also called 'hyperspectral imaging' or 'imaging spectrometry', is based on combination of imaging and spectroscopy in a single scheme. The very initial definition for imaging spectrometry was given as 'the acquisition of images in hundreds of contiguous, registered, spectral bands such that for each pixel a radiance spectrum can be derived' (Goetz, 2009). Hyperspectral sensors are the instruments which acquire images of the object in very many and very narrow (nanometre level) contiguous spectral bands. Depending on the construction, they can sense the electromagnetic waves in the ultraviolet, visible, near infrared, mid infrared and even thermal ranges of the spectrum. These instruments can collect hundreds or even more bands of data for every pixel of an image. The result is a package of images, in which each image's pixels are recorded in a single spectral band. The amount of images in this 'package' is equal to the number of spectral bands acquired. These 'packages' of data are usually called hyperspectral cubes. The XY axis of such a cube represents the spatial data, and the Z axis represents the spectral data. Such a huge amount of narrow waveband data has much bigger potential for discriminating the features of sensed objects, while information is not lost within the coarse bandwidths like it sometimes does in multispectral sensors (Lillesand et al., 2008). Hyperspectral sensing has a potential for precise identification or discrimination as well as classification of various objects and their features which usually are not solved by multispectral remote sensing systems, for example, a detailed classification of the objects in the hyperspectral image and (or) evaluation of objects' physiological, chemical and other characteristics. Big volumes of acquired data, hundreds of wavebands, very narrow spectral interval, strong correlation among adjacent wavebands, information redundancy are typical for hyperspectral remote sensing. So the researcher, who is dealing with hyperspectral data, faces new challenges like treatment of high-dimensional data, requirement for big computation capacity and data storage resources (Varshney and Arora, 2004).

Hyperspectral remote sensing is utilized in many applications like geology, hydrology, agriculture, food industry etc. (Abd-Elrahman et al., 2011; Barbin et al., 2012; Erives and Fitzgerald, 2005; Van der Meer et al., 2012). During the last decade the research in application of hyperspectral imaging in forestry was increasing as well. We could roughly classify these studies into 2 categories: 1) employment of airborne or spaceborne hyperspectral sensors. The hyperspectral images are acquired for relatively big areas and are analyzed mainly dealing with various identification, discrimination or classification approaches; 2) exploration of in situ acquired hyperspectral data (under field or laboratory conditions), mainly dealing only with the spectral part of the hyperspectral cubes, recorded for relatively small objects like a plant, branch or leaf. The aim of latter category usually is to investigate which portion of spectrum or even which waveband contributes most to the spectral separability of different plant species or (and) their condition. The spectrums obtained in situ are fundamental in the building of spectral libraries – a set of laboratory

spectra for various materials. Developing spectral libraries is a key to improving the capability to utilize the full mapping potential based on hyperspectral data (Zomer at al., 2009).

To date, one may find quite many studies which have been dealing with hyperspectral data at a single plant level, indicating that the field or laboratory taken hyperspectral measurements can significantly contribute to the discrimination of plants on species level (Castro-Esau et al., 2004; Manakos, 2003; Manevski et al., 2011; Vaiphasa et al., 2005; Zhang et al., 2006).

This paper is aimed to introduce the first attempts of hyperspectral remote sensing research in Lithuanian forestry starting with a single plant level reflectance data study. This study is focused on discrimination abilities between Scots Pine (*Pinus Sylvestris L.*) and Norway Spruce (*Picea Abies L.*), which are the most common and commercially important tree species. Scots pine stands make up 35.3% and spruce 20.8% of total forest area (State Forest Service, 2011). These coniferous tree species were selected for our research since they have always been on the margin between true and false discrimination on the remotely sensed images (e.g. digital color infrared aerial photographs) used in forest inventory in Lithuania, too (Mozgeris, 2004). They were under the focus of spectral reflectance research in Lithuania using old-fashioned spectral radiometers providing just an average reflectance curve for the object being sensed two decades ago, too. This research mainly was focused on the spectral measurements of needles and branches of trees with different defoliation level. Most effective spectral zones for defoliation assessment were set and some methodological solutions for improved spectral measurement process were suggested (Repšys, 1992).

The discussion on the discrimination between pine and spruce has a long history both in forestry remote sensing research and methodologies within the frames of operational forest inventories. The level to which these tree species can be recognized on aerial photography is determined by the type of aerial film or digital sensor, scale of photography and quality of images, and the methods used for interpretation. Even there are some differences in color and tone of tree crown projections, first of all the shape of own shadow and tree crown projection play the most important role in identification of these tree species (Mozgeris and Daniulis, 1997; Mozgeris, 2004). Most of previous research, e.g. in Lithuania, has focused on theoretical potential to discriminate between spruce and pine growing on pure stands. However, identification of the shares of pine and spruce trees on mixed stands has always been problematic (Mozgeris, 2004).

The hyperspectral imagery is supposed to significantly support the tasks of tree species discrimination. It could serve as a new solution in forest inventory for a remote identification of tree species, especially in combination with airborne laser scanning. We suppose that the future of Lithuanian forest inventory lies in much wider usage of remotely sensed data. The potential of laser scanned data for estimation of basic tree or stand parameters, such as volume, height is already proven by international and local researchers (Mozgeris and Bikuvienė, 2011; Næsset et al., 2004; Næsset, 2007), but tree species identification remains problematic so far. The potential hyperspectral imaging for tasks in Lithuanian forest inventory and internationally needs to be investigated because of invention of new generation of hyperspectral cameras, as is the VNIR400H used in our study, too.

The aim of current study is to check some methodological issues in processing of in situ acquired hyperspectral data. The objectives are as follows:

1. To verify the significance of spectral differences of Scots pine and Norway spruce using spectral imaging techniques.
2. To check whether there is a significant spectral variation among trees of the same species.
3. To check if the spectral response of northern and southern side of the same tree varies significantly.
4. To determine the wavebands which best represent the spectral differences between Scots pine and Norway spruce.

Materials and Methods

The samples were taken in 20 years old mixed Norway spruce-Scots pine plantation. The best growing trees in the plantation were randomly selected for taking samples. The middle-upper part of the crown of each tree was easily reached and the sample branches were cut from the ground using telescopic cutter. There were three trees of pine and three trees of spruce selected totally. For each tree nine sample branches were cut from the northern side of the crown and nine sample branches from the southern side of the crown. Totally 18 samples for scanning were obtained from each tree, i.e. 54 for each tree species or 108 samples in total.

Sample acquisition was performed in January, 2012. Cut samples were packed into plastic bags with some snow added. Bags were labelled, put into a portable cooler bag and transported to the laboratory for spectral measurements.

The scanning process was conducted using a Themis Vision Systems LLC new generation hyperspectral camera VNIR400H. This device is equipped with very sensitive VNIR spectrometer, which is capable to cover the spectral range of 400nm – 1000 nm with the sampling interval of 0.6 nm, producing 955 spectral

bands. The spatial data of scanned sample is recorded in CCD array in 1392X1000 pixel resolution. Pixel size is 6.45 μm X 6.45 μm. The camera's field of view is 30 degrees. The camera was mounted on a copy stand and positioned so that camera's lens was fixed at 40 cm above the sample at the nadir position. Two 100 W halogen lamps were employed to provide a stable electro-magnetic radiation in 400 nm – 1000 nm range. Halogen lamps were fixed symmetrically at both sides of the camera's lens and were illuminating the sample so that their light beams were crisscrossing each other above the sample.

The room, in which the scanning sessions were conducted, was darkened in order to avoid ambient light sources, which are unrelated to the true spectral signal of the leaves. The procedure of hyperspectral image acquisition then was as follows. First, only the last year's sprouts on each sample branch were located, and every needle from the last year's sprout was cut. Then needles were spread on top of a matt-black painted plate. Needles were collected into a little 'pile' in such a way that background plate was fully covered by needles. Second, the spectral response of each 'needle pile' was recorded 4 times. The background plate was rotated 90 degrees horizontally after every record in order to correct for the bidirectional reflectance distribution. These steps were repeated for each sample (108 in total). The result was 432 raw hyperspectral images of needle samples (4 for each separate sample).

Next, the radiance curve was converted to the reflectance curve for each pixel of the images. Target measurements were compared against the ones of a reference panel of known spectral reflectance (Avian Technologies LLC 99% white reference panel). The correction of the spectrometer internal current (dark current) was done as well. The resulting spectra were then smoothed using Savitzky-Golay filter function with the 4^{th} order polynomial fit and 25 data points. The steps above were repeated for each image.

Finally, the images were subset to contain just pixels representing only the needle reflectance information. The subset was made simply cropping images to designated 100X100 pixel size. After the subset procedure the resulting images contained 10000 pixels with only needle reflectance and spatial information.

Then a reflectance curve was derived from each image. Totally 4 reflectance curves were obtained for each needle sample. Imported to a spreadsheet, they were then averaged to construct one reflectance curve for each sample. In total 108 reflectance curves (54 for spruce and 54 for pine) were constructed. In a spreadsheet, each reflectance curve was treated as a series of numbers (reflectance coefficients) in 955 wavebands in 400 nm – 1000 nm. These series of numbers were used for statistical analysis.

Student's t-test was applied to compare between the spectral responses of 2 species whether they are statistically different at every spectral band. That is to say, the null hypothesis H_0: $\mu_{spruce} = \mu_{pine}$ versus the alternative hypothesis H_1: $\mu_{spruce} \neq \mu_{pine}$ was tested, where μ was the mean reflectance value of the species compared. Before conducting the test, the distribution of the spectral responses at every spectral band was assumed to be normal under the central limit theorem (N spectra>30) Then the hypothesis test was carried out using two sample t-test for each band (totally 955 spectral bands) with 95% confidence limit (α=0.05). The aim of conducted t-test was to highlight the spectral bands at which p values are greater than α, i.e. to set spectral locations at which the spectra of different species are very similar and not statistically separable from each other, and to highlight the spectral bands at which pine and spruce are most separable, i.e. to set spectral locations with the least p values.

Another field of interest was the spectral variability of the spectral response of the northern and southern parts of the trees of the same species. Student's t-test was applied to compare between the spectral responses of northern and southern parts of the crowns of trees of the same species at every spectral band. Before conducting the test, the distribution of the spectral responses was verified using Shapiro-Wilk test at 50 randomly selected spectral bands as well as the equality of statistical variances was verified for every spectral location. Then the hypothesis test was carried out using two sample t-test for every spectral band (total of 955 spectral bands) with 95% confidence limit (α=0.05). The aim of conducted test was to find out whether there is a significant spectral variation between northern and southern parts of crowns of trees of the same species and, if so, to highlight the spectral bands at which p values are less than α, i.e. to set spectral locations at which the spectra of northern and southern parts of the trees of the same species are statistically separable from each other.

One way ANOVA statistical test was applied to compare the spectral variability inside the same tree species, i.e. to check whether there are statistical differences among spectral responses of the same tree species at every spectral band. The null hypothesis H_0: $\mu_{tree1} = \mu_{tree2} = \mu_{tree3}$ versus alternative hypothesis H_1: $\mu_{tree1} \neq \mu_{tree2} \neq \mu_{tree3}$ was tested, where μ was the mean reflectance value of the species compared. Before conducting the test, the distribution of the spectral responses at 50 randomly selected spectral bands was verified using Shapiro-Wilk tests as well as the equality of statistical variances were verified. Then, the hypothesis test was carried out using one way ANOVA at every spectral location (total of 955 spectral bands) with 95% confidence limit (α=0.05).

The aim of conducted test was to find out whether there is a significant spectral variation among the trees of the same species and, if so, to highlight the spectral bands at which p values are less than α, i.e. to set spectral locations at which the spectra of the same species are statistically separable from each other.

Descriptive technics of discriminant analysis was used aiming to detect the spectral bands which mostly contribute to the discrimination of tree species (pine and spruce). The U statistic (Wilks' Lambda) and F statistic were calculated for each waveband (955 in total). Then the bands were ranked according to the value of U statistic in ascending order first, then according to the value of F statistic in descending order. As a result the waveband which best separates two groups (Scots pine and Norway spruce) was ranked at top.

Principal component analysis was employed in this study to display the trends of differences of the samples of each tree species graphically. Each tree sample was plotted as a dot in a two dimensional scatter-plot, where X axis represented first principal component and Y axis represented second principal component.

Results and Discussion

This study aimed to answer some methodological questions on processing of in situ acquired hyperspectral data. Therefore, samples just from one test area were decided to be used for this study. The test objects had to provide possibilities to take samples from the middle-upper part of the tree's crown, trees of both species had to have the identical growth conditions (grow on the same site) and be the same age. Thus 20 years old well grown and tended mixed spruce-pine plantation was selected as an optimal choice.

Student's t-test for two samples is employed when the comparison of average values in two populations must be conducted. In our case two populations are represented by two groups of measurements, one for Norway spruce, the other for Scots pine, taken in 955 spectral bands in 400 nm – 1000 nm range. The result of Student's t-tests revealed that reflectance in 865 of 955 spectral bands was statistically different in spruce and pine spectra (p-values below 0.05). The least informative (p-values above 0.05) was 821.9 nm – 886.6 nm spectral range (near infrared plateau), in which pine and spruce reflectance signals were not statistically different; thus, they are not supposed to serve for separation between Norway spruce and Scots pine (see Figure 1, a). Spectral range at 666.5 nm – 668.4 nm was rated as most informative one for spruce – pine separation. Here the reflectance signals appeared to be most statistically different (p-values lowest). Waveband at 667.1 nm was rated as the most informative in Norway spruce – Scots pine species detection.

Some authors conclude extensive amount of variability to be found in the spectral response of foliage within same species and even within same tree (Cochrane, 2000; Im and Jensen, 2008; Price, 1994). In our study another task for Student's t-test was to evaluate differences of the same species needles reflection depending on which side of tree crown, northern or southern, they were grown (Figure 2). Test results for Norway spruce detected no significant differences in 833 wavebands. In 122 wavebands, however, the reflectance differences were statistically significant. Majority of statistically different bands formed a range of 594.9 nm – 665.8 nm (see Figure 2, b). Test results for Scots pine showed a different pattern (Figure 2, a). Reflectance signals were statistically similar only in 55 wavebands ranging in 697.2 nm – 727.2 nm. Reflectance signals in the rest of the spectrum (900 wavebands) showed no statistical similarity.

The influence of the crown side regarding the Sun location on variance of reflectance of needles for Scots pine might be explained by the nature of this

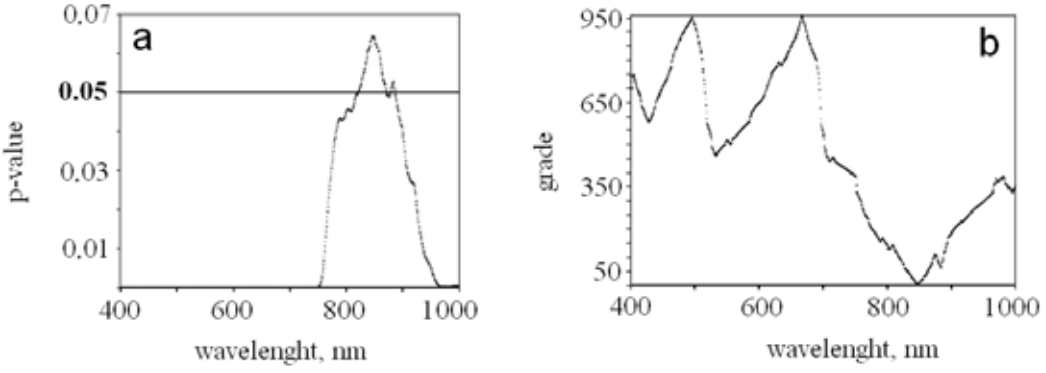

Figure 1. Separability between Scots pine and Norway spruce: (a) results of Student's t-test (range of p-values); (b) grades of discriminant analysis (1 – lowest separability, 955 – highest separability).

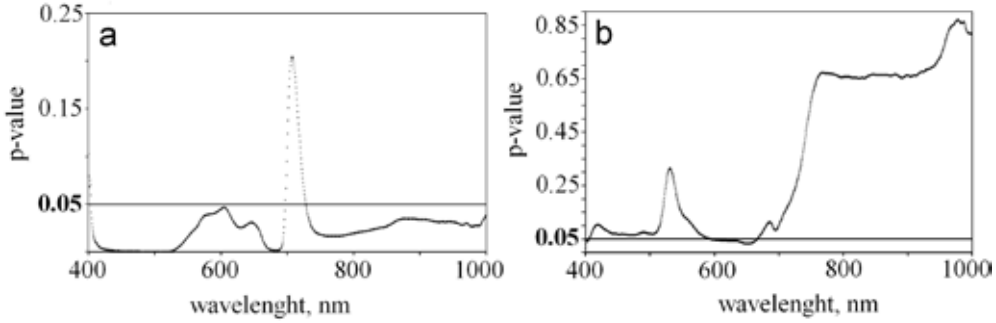

Figure 2. Results of Student's t-test (range of p-values) for Scots pine (a) and Norway spruce (b) spectral separability test depending on needle aspect in the crown.

species. It is a light demanding tree. Hence chemical and structural characteristics of pine needles more exposed to the sun differ from those which are longer in the shade. Norway spruce is a shade tolerant tree. Its north and south exposed needles spectral comparison shows relatively low reflectance variation compared to Scots pine.

ANOVA test was conducted to evaluate the spectral variability inside the same tree species at every spectral band. ANOVA provides a statistical test if the means of several groups are different; thus, ANOVA generalizes Student's t-test for more than two groups (Čekanavičius and Murauskas, 2002). In our case ANOVA was conducted for three groups of measurements (for 3 trees) for Norway spruce and Scots pine respectively (Figure 3). Results of 955 ANOVA tests indicated that for spruce the hypothesis that there is a significant variation among every single tree at every spectral band cannot be rejected. For Scots pine, ANOVA test showed a slightly different results. Only 356 spectral bands of 955 were significantly different among separate Scots pine trees. Those bands were distributed into 3 separate ranges: 400-446.2 nm, 523.5 – 637.1 nm and 693.3 – 752.0 nm.

Discriminant analysis may be used for two objectives: either to set the attributes which best contribute to the separation of the groups of objects under study (in our case tree species), or to assign objects to one of a number of known groups of objects. Thus, discriminant analysis may have a descriptive or a predictive objective (Čekanavičius and Murauskas, 2002). Discriminant analysis was conducted as an alternative and more convenient way to discriminate between groups than Student's t-test. Moreover, the discriminant analysis can deal with more than 2 groups, unlike t-test. U statistic and F statistic were calculated for every waveband (totally 955). Then the bands were ranked according to the value of U statistic in ascending order first, then according to the value of F statistic in descending order. As a result, the waveband which best separates two groups (pine and spruce) was ranked at top. As it was expected, the results are identical to the ones received by the t-test. Best discriminating waveband was set at 667.1 nm, best discriminating spectral range 666.5 nm – 668.4 nm (Figure 1, b). Discriminant analysis reveals its full potential in classification tasks. That's why absolute majority of studies dealing with forest hyperspectral imagery employ discriminant analysis for predictive objectives in images classification (Clark et al., 2005; Dalponte et al., 2009; Thenkabail et al., 2004).

Principal component analysis is a method of an analysis of a data matrix consisting of inter-correlated quantitative dependent variables. Principal component analysis is the way to extract the most important

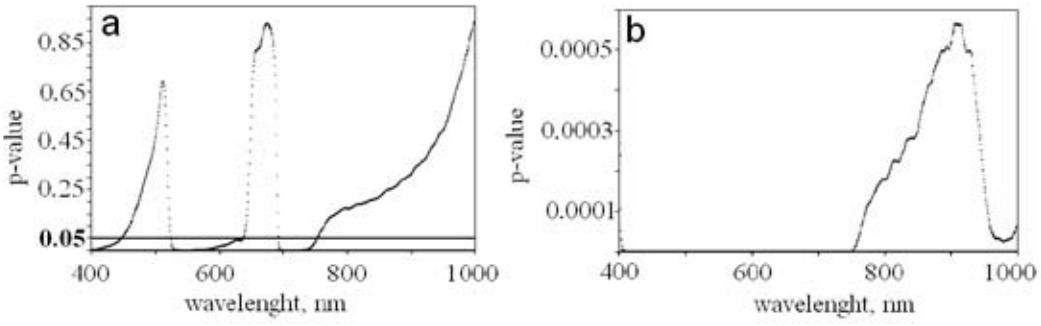

Figure 3. Results of ANOVA (range of p-values) for Scots pine (a) and Norway spruce (b) for spectral variability among separate sample trees.

information from the data matrix and to represent it as a set of new orthogonal variables called principal components (Čekanavičius and Murauskas, 2002). In this study all 108 measurements of tree samples were averaged to represent only each single tree selected for research. This was considered to serve for more convenient interpretation of results of the analysis. That is, data of 6 spectral curves (3 for spruce and 3 for pine) were loaded to principal component analysis. The results of principal component analysis are presented in Figure 4. This is a two-dimensional scatter plot of scores of two most important components from analysis, where X axis represents first principal component, but Y axis represents second principal component.

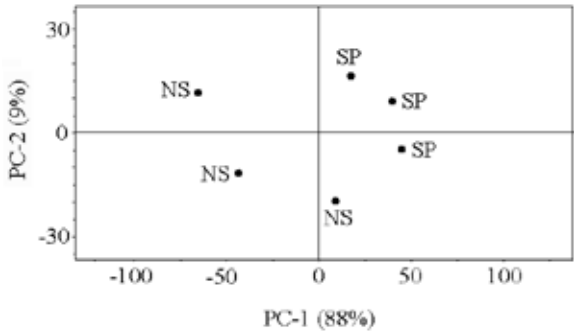

Figure 4. Scores of principal component (PC) analysis for Scots pine (SP) and Norway spruce (NS).

The plot provides information about patterns in the samples. The closer the samples are in the scores plot, the more similar they are with respect to the two components concerned. Conversely, samples far away from each other are different from each other. The plot can be used to interpret differences and similarities among samples. The plot proves that Scots pine and Norway spruce are spectrally separable from each other. General separability trend between pine and spruce is best described by the first principal component. The dots representing Scots pine tend to form a group while dots representing Norway spruce tend to spread. Thus, spectral similarity among separate Scots pine sample trees appears to be relatively good while spectral similarity among Norway spruce trees - relatively poor. The results of ANOVA test validate this conclusion.

The use of in situ spectral measurements for species discrimination is often employed at both laboratory level or field level (Adam and Mutanga, 2009; Castro-Esau et al., 2004; Cochrane, 2000; Hesketh and Sánchez-Azofeifa, 2012; Kalacska et al., 2007; Manakos, 2003; Manevski et al., 2011; Vaiphasa et al., 2005; Zhang et al., 2006). Every study combines its own approaches to the statistical treatment of reflectance data. Apparently, there is no universal method for the optimal feature selection in hyperspectral data treatment.

In this study no effort to decrease data redundancy between adjacent bands was made. Our goal was to use the full possible range of data of all narrow wavebands recorded by the hyperspectral camera. Thus, we were sure not to lose any important information that single adjacent band could contain to the researched object.

Conclusions

This study revealed that:

1. A significant variation in spectral response of needles of Norway spruce exists across whole measured spectral range (955 wavebands) for each sample tree.
2. A significant variation in spectral response of needles of Scots pine exists only in 356 of 955 recorded wavebands for each sample tree. The significant variance of spectral signatures among single trees, especially of Norway spruce, suggests expanding the field of research seeking to motivate such variation. The research could involve a wider sample trees selection including different sites, tree age and growth conditions.
3. Depending on the aspect of a tree crown, the reflectance of Scots pine needles differed significantly in 900 out of 955 measured spectral bands. This variance of reflectance might be explained by the light demanding nature of Scots pine.
4. The Scots pine and Norway spruce spectral measurements proved that the discrimination of these two species is possible at the laboratory level hyperspectral imaging. This is a good prerequisite to use airborne hyperspectral sensor for future investigations of the potential of hyperspectral imaging in application in forest inventory of Lithuania.

References

1. Abd-Elrahman A., Croxton M., Pande-Chettri R., Toor G.S., Smith S., Hill J. (2011) In situ estimation of water quality parameters in freshwater aquaculture ponds using hyperspectral imaging system. *ISPRS Journal of Photogrammetry and Remote Sensing*, 66, pp. 463–472.
2. Adam E., Mutanga O. (2009) Spectral discrimination of papyrus vegetation (Cyperus papyrus L.) in swamp wetlands using field spectrometry. *ISPRS Journal of Photogrammetry and Remote Sensing*, 64, pp. 612–620.

3. Barbin D., Elmasry G., Sun D., Allen P. (2012) Near-infrared hyperspectral imaging for grading and classification of pork. *Meat Science*, 90, pp. 259–268.
4. Castro-Esau K.L., Sanchez-Azofeifa G.A., Caelli T. (2004) Discrimination of lianas and trees with leaf-level hyperspectral data. *Remote Sensing of Environment*, 90, pp. 353–372.
5. Čekanavičius V., Murauskas G. (2002) *Statistika ir jos taikymai (Statistics and its application)*, TEV, Vilnius, LT, 272 p. (in Lithuanian).
6. Clark M.L., Roberts D.R., Clark D.B. (2005) Hyperspectral discrimination of tropical rain forest tree species at leaf to crown scales. *Remote Sensing of Environment*, 96, pp. 375–398.
7. Cochrane M.A. (2000) Using vegetation reflectance variability for species level classification of hyperspectral data. *International Journal of Remote Sensing*, 21 (10), pp. 2075–2087.
8. Dalponte M., Bruzzone L., Vescovo L., Gianelle D. (2009) The role of spectral resolution and classifier complexity in the analysis of hyperspectral images of forest areas. *Remote Sensing of Environment*, 113, pp. 2345–2355.
9. Erives H., Fitzgerald G.J. (2005) Automated registration of hyperspectral images for precision agriculture. *Computers and Electronics in Agriculture*, 47, pp. 103–119.
10. Goetz A.F.H. (2009) Three decades of hyperspectral remote sensing of the Earth: A personal view. *Remote Sensing of Environment*, 113, pp. 5–16.
11. Hesketh M., Sánchez-Azofeifa G.A. (2012) The effect of seasonal spectral variation on species classification in the Panamanian tropical forest. *Remote Sensing of Environment*, 118, pp. 73–82.
12. Im J., Jensen R. (2008) Hyperspectral Remote Sensing of Vegetation. *Geography Compass*, 2/6, pp. 1943–1961.
13. Kalacska M., Bohlman S., Sanchez-Azofeifa G.A., Castro-Esau K., Caelli T. (2007) Hyperspectral discrimination of tropical dry forest lianas and trees: Comparative data reduction approaches at the leaf and canopy levels. *Remote Sensing of Environment*, 109, pp. 406–415.
14. Lillesand T.M., Kiefer R.W., Chipman J.W. (2008) *Remote Sensing and Image Interpretation, 6th ed*, Wiley, New York, USA, 756 p.
15. Manakos I., Manevski K., Petropoulos G.P., Elhag M., Kalaitzidis C. (2010) Development of a Spectral Library for Mediterranean Land Cover Types. In: *Proceedings of the 30th EARSeL Symposium: Remote Sensing for Science, Education and Natural and Cultural Heritage*, pp. 663–668.
16. Manevski K., Manakos I., Petropoulos G.P., Kalaitzidis Ch. (2011) Discrimination of common Mediterranean plant species using field spectroradiometry. *International Journal of Applied Earth Observation and Geoinformation*, 13, pp. 922–933.
17. Mozgeris G. (2004) Miškotvarkoje naudojamų ortofototransformuotų aerovaizdų dešifravimo požymiai (The features of orthophotos used for forest inventory). *Miškininkystė*, 1(55), pp. 49–59. (in Lithuanian).
18. Mozgeris G., Bikuvienė I. (2011) Airborne Laser Scanning for Stand-Wise Forest Inventories: a Case Study in Lithuania. In: *Biennial International Symposium „Forest and Sustainable Development", "Transilvania" University of Brasov, Faculty of Silviculture and Forest Engineering*, Transilvania University Press, pp. 447–452.
19. Mozgeris G., Daniulis J. (1997) Medžių rūšių dešifravimo požymiai juodai baltose vidutinio mastelio (1:10000-1:200000) aerofotonuotraukose (The features of identification of tree species in panchromatic average scale (1:10000-1:20000) aero photos). *Miškininkystė*, 2(40), pp. 40–48. (in Lithuanian).
20. Næsset E. (2007) Airborne laser scanning as a method in operational forest inventory: status of accuracy assessments accomplished in Scandinavia. *Scandinavian Journal of Forest Research*, 22, pp. 433–442.
21. Næsset E., Gobakken T., Holmgren J., Hyyppä H., Hyyppä J., Maltamo M., Nilsson M., Olsson H., Person A., Söderman U. (2004) Laser scanning of forest resources: the Nordic experience. *Scandinavian Journal of Forest Research*, 19, pp. 482–499.
22. Price J.C. (1994) How unique are spectral signatures? *Remote Sensing of Environment*, 49, pp. 181–186.
23. Repšys J. (1992) Teršalų pažeistų spygliuočių optinės savybės (The optical properties of coniferous trees damaged by air pollution). *Mūsų girios*, 1, pp. 2–4. (in Lithuanian).
24. State Forest Service (2011) *Lithuanian statistical yearbook of forestry*, Lututė, Kaunas, LT, 184 p.
25. Thenkabail P.S., Enclona E.A., Ashton M.S., Van Der Meer B. (2004) Accuracy assessments of hyperspectral waveband performance for vegetation analysis applications. *Remote Sensing of Environment*, 91, pp. 354–376.
26. Vaiphasa Ch., Ongsomwang S., Vaiphasa T., Skidmore A.K. (2005) Tropical mangrove species discrimination using hyperspectral data: A laboratory study. *Estuarine, Coastal and Shelf Science*, 65, pp. 371–379.

27. Van der Meer F.D., Van der Werff H.M.A., Van Ruitenbeek F.J.A., Hecker C.A., Bakker W.H., Noomen M.F., Van der Meijde M., Carranza E.J.M., De Smeth J.B., Woldai T. (2012) Multi- and hyperspectral geologic remote sensing: A review. *International Journal of Applied Earth Observation and Geoinformation*, 1, pp. 112–128.
28. Varshney P., Arora M. (2004) *Advanced Image Processing Techniques for Remotely Sensed Hyperspectral Data*. Springer Press, Berlin, D, 322 p.
29. Zhang J., Rivard B., Sánchez-Azofeifa A., Castro-Esau K. (2006) Intra- and inter-class spectral variability of tropical tree species at La Selva Costa Rica: implications for species identification using HYDICE imagery. *Remote Sensing of Environment*, 105, pp. 129–141.
30. Zomer R.J., Trabucco A., Ustin S.L. (2009) Building spectral libraries for wetlands land cover classification and hyperspectral remote sensing. *Journal of Environmental Management*, 90, pp. 2170–2177.

DISTRIBUTION AND STATUS OF COMMON JUNIPER (*JUNIPERUS COMMUNIS* L.) IN LITHUANIAN PINE STANDS

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Abstract
Distribution and status of common juniper (*Juniperus communis* L.) in Lithuanian Pine stands are investigated in the study. The research was conducted in pure pine stands on sites with normal humidity and poor fertility in South – South Eastern parts of Lithuania. 40 stands were selected for data collection. Temporary rectangular sample plots with area of 10 m² were selected. According to method of underbrush evaluation, diameter root neck level, height and state index was measured for 3 juniper individuals located near tthe center of sample plots. The number of sample plots depended on the area of each stand, but it was not lower than 10 in each stand. Average diameter of junipers was 3.03 cm, average height – 2.03 m. It was determined that average density of juniper individuals is 5055 individuals per hectare, and separately in *vacciniosum* and *vaccinio – myrtilosum* forest types - 4844 and 5282 individuals per hectare respectively. Average state index of juniper individuals in 6 grade scale was 2.96, which is near to grade 3 (slightly damaged). Results of the study show that distribution, status and dendrometric characteristics of junipers are different in adjacent regions of pine provenance.
Key words: common juniper, distribution, status.

Introduction

Common juniper (*Juniperus communis* L.) is a typical plant in underbrush of forest stands growing in ecosystems with less fertile and more dry soils. Its habitat covers almost all Europe and North America, reaches Northern Africa and grows in different regions of Asia up to eastern part of Kamchatka peninsula (Plantlife, 2007). The species is distinguished by high ecological flexibility and variety of populations (Adams, 2008). In many regions on the habitat it plays an important role in ecosystems; however, the ecological importance of the species is being investigated only occasionally, mostly in North America (Adams, 2008), British Isles (Thomas, 2007), some regions of Russia (Тишкина, 2009). In Lithuania, investigations of common juniper is mostly limited by research of essential oil composition (Butkienė et al., 2009) or possibilities to use juniper as biomonitor (Čeburnis and Stainnes, 2009).

According to the data of Lithuanian National Forest Inventory (Lithuanian State Forest Service, 2011), common juniper is abundantly spread in pine stands. However, no detailed investigation on distribution of the species has been made.

The aim of the study is to investigate distribution and status of common juniper in Lithuanian pine stands.

Materials and Methods

The subject of the study was pine stands in South – South Eastern Lithuania growing in normal humidity and low fertility sandy soils. The age of the stands was from 25 to 115 years. The stands were divided into 4 age groups (young, mid-aged, premature, mature), 10 stands representing each group were selected. The type of soil was the same in all stands, and types of the forest were *vacciniosum* and *vaccinio – myrtilosum*.

Only stands exceeding 1 hectare were selected for sampling. The requirement for selection was that no silvicultural activity should be carried out in the stands during past 10 years. According to method of underbrush valuation, temporary sample plots of 10 m² were marked in systematic method. The number of sample plots depended on the area of each stand and were located in diagonal direction to the shape of the stands. In each sample plot, diameter root neck level, height and state was measured for 3 juniper individuals nearest to the center of the sample plots.

Total number of juniper individuals in each sample plot was calculated. The state of individuals was estimated using 6 grade scale (Žiogas, 2005): healthy, slightly/moderately/strongly damaged, fresh dried, old dried.

The data represents South – South Eastern Lithuania as a whole and two separate regions of pine provenance which are selected according to genetic, ecological and geographical similarities as well as climatic and natural diversity (Department of Forests and Protected Areas; Lithuanian Forest Research Institute, 1999).

Statistical data processing was carried out by common methods of mathematical statistics using "Statistica 9.0" software.

Results and Discussion

The average diameter of junipers was 3.03±0.08 cm, average height – 2.03±0.04 m. The characteristics were different in separate regions of provenance (Table 1). It was indicated that juniper individuals reach higher diameter and height in the 3rd region of pine provenance (significance $p<0.05$).

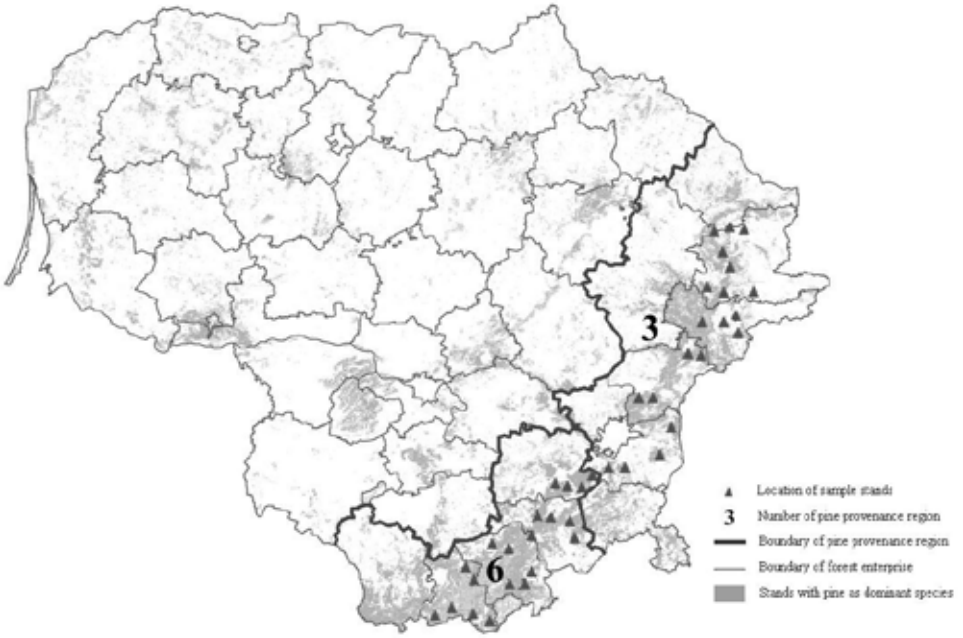

Figure 1. Distribution of research areas.

Table 1

Dendrometric characteristics of juniper individuals (significance p<0.05)

Characteristics	South – South Eastern Lithuania	3rd region of pine provenance	6th region of pine provenance
Diameter, cm	3.03±0.08	3.45±0.14	2.72±0.09
Height, m	2.03±0.04	2.29±0.06	1.83±0.04

Average density of junipers in the underbrush of selected stands was 5055±268 individuals per hectare. The higher density was indicated in the 6th region of pine provenance (Fig. 1) reaching 5750±407 individuals per hectare, the lowest – in the 3rd region of pine provenance, 4087±288 individuals per hectare. The difference in density of juniper individuals in the regions was statistically significant (significance p<0.05) and was close to 20%.

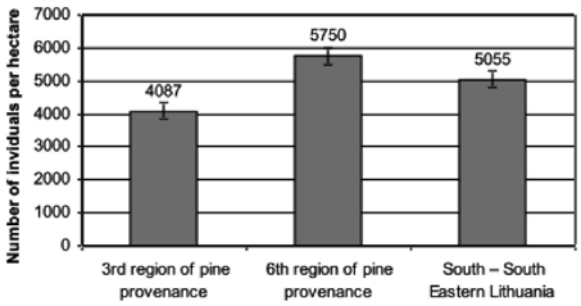

Figure 2. Density of juniper underbrush in different regions of pine provenance.

Results on density of junipers in different types of forest (Fig. 3) show that there is no significant difference in juniper underbrush density in *vacciniosum* and *vaccinio – myrtilosum* forest types (significance p>0.05).

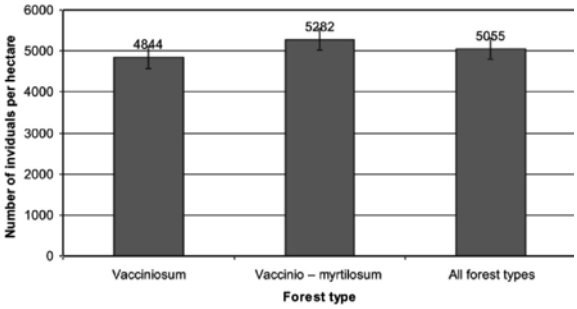

Figure 3. Density of juniper underbrush in different forest types.

Analysis of juniper underbrush status shows (Fig. 4) that moderately and strongly damaged individuals prevail (55.6%) in selected stands.

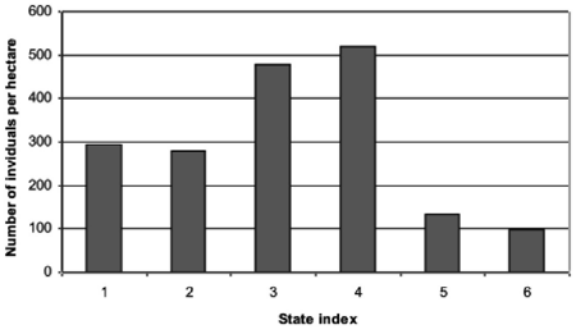

Figure 4. Distribution of junipers by state index in South – South Eastern Lithuania.

Comparison of status and number of junipers in separate regions indicated that the 6th region of pine provenance differs in better status of juniper individuals (Table 2).

The average state index in all selected stands was 3.12±0.06 (Table 2). The index was significantly (significance $p<0.05$) higher in the 6th region of pine provenance (3.23±0.07) compared to the 3rd region of pine provenance (2.91±0.08).

Results of the study show that distribution of junipers as well as status of individuals and their dendrometric characteristics vary in relatively similar natural conditions. Even in the same type of site and in stands of the same species composition, the characteristics are significantly different in adjacent geographic regions. The results confirm conclusions made in other parts of juniper habitat that common juniper is sensitive to various natural conditions (Plantlife, 2007); however, it is widely spread in different sites because of ecological flexibility and infraspecific variation (Михеева, 2002; Adams, 2008).

Conclusions

1. Average diameter of junipers in South – South Eastern Lithuania is 3.03 cm, average height – 2.03 m. The characteristics are different in separate regions of pine provenance (significance $p<0.05$).
2. Average density of junipers in pine stands of South – South Eastern Lithuania is 5055 individuals per hectare. Higher density is indicated in the 6th region of pine provenance compared to the 3rd region of pine provenance (significance $p<0.05$), the difference is near to 20%.
3. Average status index of juniper individuals in South – South Eastern Lithuania is 3.12. The index is significantly (significance $p<0.05$) higher in the 6th region of pine provenance compared to the 3rd region of pine provenance.

Table 2

Distribution of junipers by state and average state indexes index in South – South Eastern Lithuania

	State index							Average state
	1	2	3	4	5	6	Iš viso	
	South – South Eastern Lithuania							3.12±0.06
Number of individuals	293	280	478	521	134	97	1806	
%	16.2	15.5	26.6	28.8	7.4	5.4	100	
	3rd region of pine provenance							2.91±0.08
Number of individuals	114	130	153	150	44	22	613	
%	18.6	21.2	25.0	24.5	7.2	3.6	100	
	6th region of pine provenance							3.23±0.07
Number of individuals	179	150	325	371	90	75	1193	
%	15.0	12.6	27.5	31.1	7.5	6.3	100	

References

1. Adams R.P. (2008) Junipers of the World: The Genus Juniperus. Trafford Publishing Co, Vancouver, Canada, 402 p.
2. Butkienė R., Nivinskienė O., Mockutė D.M. (2009) Two chemotypes of essential oils produced by the same Juniperus communis L. growing wild in Lithuania. Chemija, 20/3, pp. 195–201.
3. Čeburnis D., Steinnes E. (2000) Conifer needles as biomonitors of atmospheric heavy metal deposition: comparison with mosses and precipitation, role of the canopy. Atmospheric Environment, 34, pp. 4265–4271.

4. Department of Forests and Protected Areas, Lithuanian Forest Research Institute (1999) Lietuvos miško sėklinis rajonavimas (Selection of Seed Regions in Lithuanian Forests). Lututė, Kaunas, 42 p. (in Lithuanian).
5. Lithuanian State Forest Service (2011) Lithuanian Forest Statistics 2011. Lututė, Kaunas, 176 p.
6. Plantlife (2007) UK Biodiversity Action Plan. Available at: http://www.plantlife.org.uk/uploads/documents/Juniperus_communis_Dossier_ part1.pdf, 2 February 2012.
7. Thomas P.A. (2007) El-Barghati M., Polwart Biological Flora of the British Isles: Juniperus communis L. Journal of Ecology, 95, pp. 1404–1440.
8. Žiogas A. (ed.) (2005) Augalų apsaugos vadovas (Plant Protection Guide). - Kaunas, Lututė, pp. 283–285. (in Lithuanian).
9. Тишкина Е.А. (2009) *Закономерности распространения, формовое разнообразие и экологическая приуроченность Juniperus communis L. на Урале*. *(Regularities of Distribution, Variance of Forms and Ecological Confinement of Juniperus communis Lin Ural)* — Екатеринбург. 135 с. (in Russian).
10. Михеева Н.А. (2002) *Изменчивость жизненных форм можжевельника обыкновенного (Juniperus communis L.) в условиях болота и суходола (Variability of Life Forms of Common Juniper (Juniperus communis L.) in Wet and Dry Soils).* Ботанические исследования в Сибири. Вып. 11. Красноярск: Красноярское отделение Российского ботанического общества РАН. с. 105-110. (in Russian).

THE ASSESMENT OF VEGETATION DIVERSITY IN BLACK ALDER WOODLAND KEY HABITATS IN ZEMGALE

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Abstract
The article focuses on vegetation diversity in the black alder *Alnus glutinosa* (L.) Gaertn. woodland key habitats in Zemgale, Latvia. Together nine sample plots were established on these habitat types, where next stand South – South West (S-SW) side at the age 1-10; 20-30 and 40-50 years. The vegetation survey has been made in vegetation period of 2010 and 2011. Braun – Blanque method has been used to estimate the projective coverage (%) of tree layer (E3), shrub layer (E2), herb layer (E1) and moss layer (E0) in order to assess the edge effect impact on vegetation diversity according to different ages classes in a next stands of sample plots. The analysis of edge effect verifies that there is a significant influence from the edge in 1st and 3rd zones of sample plots, which lies at S-SW side at the ages 1-10 and 20-30. In sample plots several indicator species of black alder woodland key habitats have been found: *Vaccinium myrtillus* L., *Lycopus europaeus* L., *Iris pseudacorus* L., *Comarum palustre* L., *Plagiomnium ellipticum* (Brid.)T.kop. Ordination confirmed that composition of species are relatively close, which demonstrate that species are able to live in similar type growing conditions. Protective species *Circaea lutetiana* L. and *Plagiothecium undulatum* (Hedw.) B., S. et G were found on the study sites. Also, adventive species *Impatiens parviflora* DC was found. Comparing the analysis by zones and sample plots and different age classes, the impact on edge effect has been distinguished in black alder woodland key habitats.
Key words: edge effect, *Alnus glutinosa*, vegetation survey, woodland key habitats, swamp woods.

Introduction

As a result of increasing forestry activity, the forest fragmentation has raised up (Aune et al., 2005), which leaves an impact on woodland key habitat types, structural elements and species (Hallanaro and Pylvanainen, 2001). Forest as ecosystem can be characterized by vegetation – plant communities, dominant species, sinusial or dominant association (the combination of vegetation stands) (Priedītis, 1999). Black alder *Alnus glutinosa* (L.) Gaertn swamp woods have been affected by permanent or seasonal changes in water fluctuations (Auniņš et al., 2010). Inherent characteristic feature is a great diversity of species. The naturally rugged stand is a significant element in black alder swamp woods (Angelstam et al., 2005; Priedītis, 1993). The natural succession has been a long term process, whilst decayed trees and dead wood are found infrequently; almost no changes in composition of tree species and wind fallen trees have occurred quite rarely (Auniņš et al., 2010). Both important structural elements in these habitats are runts and decayed trees and particular mosaic – structure of relief. Mosaic structure provides various moisture levels in alder swamp woods, where on the typical stem spots there are meadow, nemoral and boreal type species, whereas in a lowland sites swamp and nitrophilous type species dominate (Priedītis, 1999). The high moisture level is a significant factor in swamp woods (Orzewska, 2009) and species are incredibly sensitive to the changes of microclimate (Ek et al., 2002; Madžule and Brūmelis, 2008; Priedītis, 1997). The mosaic structure on mounded places make the microrelief with typical plant communities without dominant plant species in herb layer and moss layer. The impact of determinant moisture level and light micro gradient provides high diversity of species (Ek et al., 2002). The major limited factors in herb layer and shrub layer in forest ecosystems are light and ability to adapt to obstacles in swamp woods (Tabaka, 2001); therefore, in lighter patches light tolerant species could be found, but in darker patches – shade tolerant species are located (Packham et al., 1992). The black alder swamp woods are endangered by such factors as drainage (Priedītis, 1999) and harvesting, which change equilibrium in the existing microclimate. As a result, the structure of stand is degraded, and it leaves a relevant impact on the further growth of trees. The degradation of such key habitats is also increased by the vast clear cuttings in the stands close by and beaver activities, which result in the change of species composition – reed, sedges, several willows and buckthorns are taking over it, and the natural regeneration on swamp woods is pressed out (Priedītis et al., 2002; Auniņš et al., 2010). The aim of research is to estimate the edge effect impact on the vegetation of black alder swamp wood key habitats.

Materials and Methods

Site description and vegetation survey

The research has been performed in two woodland types: *Dryopterioso caricosa* and *Filipendulosa* on wet peat soils. The research was carried out in nine different black alder woodland key habitats located in the territory of joint – stock company (JSC) 'Latvia state forests' in Zemgale region. During the vegetation seasons of 2010-2011, in each forest tract there were nine vegetation sample plots arranged and surveyed

(the area of each sample plot 20×50 m), which have been divided into five 10m wide zones from the side of stand. To the south and south west side of sample plots there are stands that correspond to 3 different groups: 1-10, 20-30 and 40-50 years old stands (in each age group there are three sample plots). The vegetation was surveyed in the first zone, third zone, and fifth zone (each zone is 200 m^2). The Braun – Blanquet method has been used to describe the plant communities (Pakalne and Znotiņa, 1992): the total projective coverage of tree (E3), shrub (E2), herb (E1) and moss (E0) layer, as well as the coverage of each separate species was evaluated in the sample plots according to the percentage. The nomenclature of vascular plants – Gavrilova, Šulcs, 1999, bryophytes – Āboliņa, 2001 was assessed.

Data processing methods

The descriptions of vegetation were summarised in the data base of MS Excel. The occurrence of plant species is characterised by the constancy class which is calculated by referring to the number of those sample plots where the species have been identified to the number of the whole group of sample plots: I - < 21, II - 21-40, III - 41-60, IV - 61-80, V - 81-100% (Muller – Dombois and Ellenberg, 1974). Data processing has been performed by means of *Community analysis package* (Pisceas Conservation Ltd.) PCA (Principal component analysis). The statistical method was applied for the evaluation of validity: one way analysis of variance (SPSS) (Arhipova and Bāliņa, 1999).

Results and Discussion

The total number of species in nine sample plots was 98, out of which seven were tree species, four - shrub species, 61 - vascular plant species and 26 - bryophytes. In the tree layer – 6, shrub layer – 5, herb layer – 69 and moss layer – 26 species were established. The total number of vascular plant and bryophyte species and sample plots by zones are shown in Figure 1.

In the 1st zones of all sample plots, 76 vascular plant and bryophyte species, out of which 5 – in the tree layer, 5 – in the shrub layer, 60 – in the herb layer and 15 species – in the moss layer were identified. In the sample plots, where the next stands on S-SW side are at the age of 1-10 years, the total number of species is 44, from which in the tree layer – 3, in the shrub layer – 4, in the herb layer – 32 and in the moss layer – 11. In the 1st zones of sample plots, where the next stands on S-SW side are at the age of 20-30 years, in general, 41 species, from which in the tree layer – 3, in the shrub layer – 5, in the herb layer – 42 and in the moss layer – 8 were found. In the sample plots, where the next stands are at the age of 40-50 years, in the 1st zones there were 41 species found in total, from which in the tree layer – 4, in the shrub layer – 5, in the herb layer – 34 and in the moss layer – 7.

In the 3rd zones of all sample plots there were 78 species identified in total, out of which 4 were in the tree layer, 5 – in the shrub layer, 57 – in the herb layer and 21 – in the moss layer. In the sample plots, where the next stands are at the age of 1-10 years, there were 50 species found in total, out of which in the tree layer – 3, in the shrub layer – 4, in the herb layer – 37 and in the moss layer – 12 species. In total there were 46 species found in the sample plots, where the next stands are at the age of 20-30 years, including 4 species in the tree layer, 4 – in the shrub layer, 36 – in the herb layer and 10 species in the moss layer. In the sample plots, where the next stands are at the age 40-50 years on S-SW side, there were 45 species found in total, out of which in the tree layer – 4, in the shrub layer – 5, in the herb layer – 32 and in the moss layer – 10 species were found.

The total number of species in the 5th zones of all sample plots is 73, out of which in tree layer – 4, in

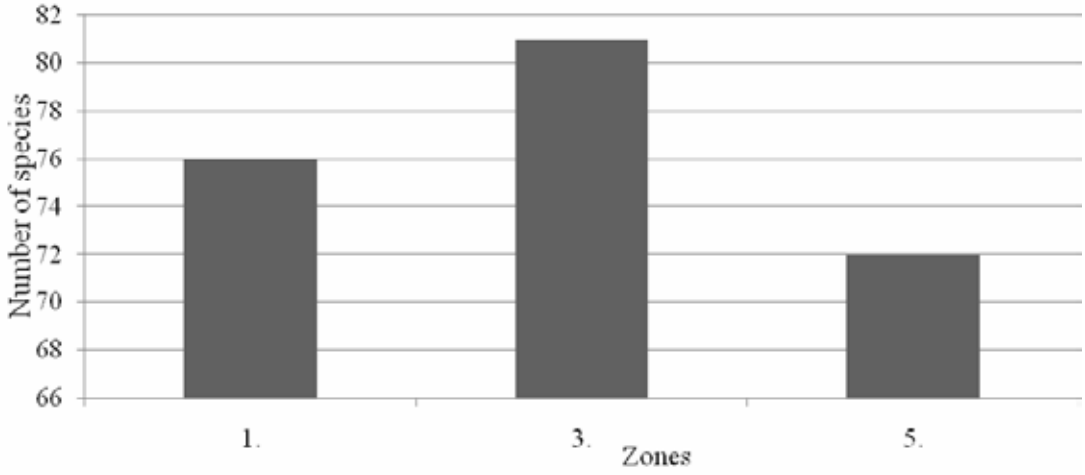

Figure 1. The number of vascular plants and bryophytes by zones. (1. – the number of species in the 1st zone; 3.- the number of species in the 3rd zone; 5. – the number of species in the 5th zone).

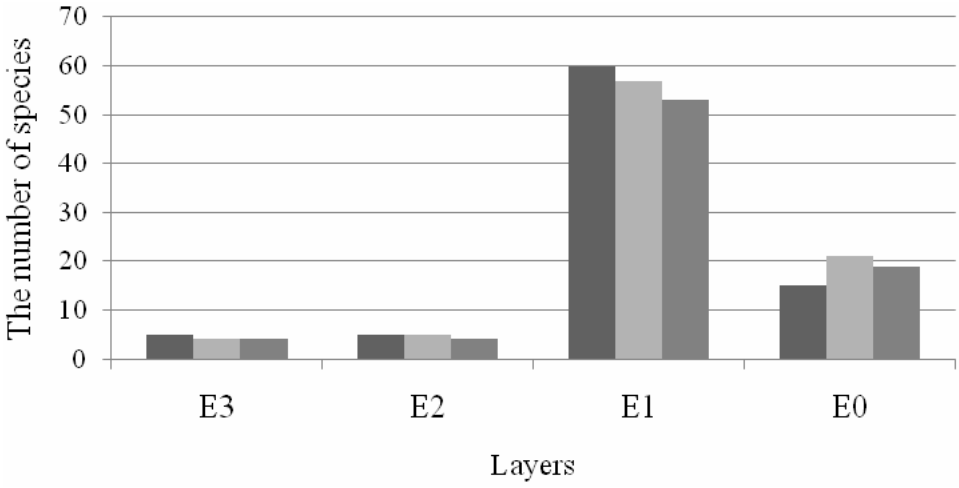

Figure 2. The division of vascular plants and bryophytes by zones.
(■ – 1st zone; ■ – 3rd zone; ■ – 5th zone; E3 – tree layer; E2 – shrub layer; E1 – herb layer; E0 – moss layer).

the shrub layer – 4, in the herb layer – 53 and in the moss layer –19 species were found. In the sample plots, where the next stands on S-SW side are at the age of 1-10 years, there were 34 species found in total, out of which in the tree layer – 4, in the shrub layer – 3, in the herb layer – 25 and in the moss layer – 8 species. In the sample plots, where the next stands on S-SW side are at the age of 20-30 years, there were 52 species found in general, out of which in the tree layer – 4, in the shrub layer – 2, in the herb layer – 39 and in the moss layer – 11 species were found. In the sample plots, where the next stands on S-SW side are at the age of 40-50 years, there were 37 species found in total, out of which in the tree layer – 3, in the shrub layer – 4, in the herb layer – 27 and in the moss layer – 8 species were found. In total, the comparison of the number of species by zones is shown in Figure 2.

Constancy

In all sample plots *Alnus glutinosa* and *Picea abies (L.)* H.Karst were found that create an important composition of species in black alder woodland key habitats (Angelstam et al., 2005). The dominant species (constancy class V) in sample plots are *Padus avium* Mill., *Betula pubescens* Ehrh., in the herb layer – *Oxalis acetosella* L., *Rubus idaeus* L., *Lycopus europaeus* L. It is frequently possible to find the following species (constancy class IV): *Equisetum sylvaticum* L., *Paris quadrifolia* L., *Filipendula ulmaria* (L.) Maxim., *Maianthemum bifolium* L., *Milium effusum L.*, *Vaccinium myrtillus* L., *Pteridium aquilinum* (L.) Kuhn. In the moss layer (constancy class III) – *Plagiomnium affine* (Bland.) T.Kop., *Polytrichum juniperinum* Hedw., *Pleurozium schreberi* (Brid.) Mitt. and *Thuidium tamariscinum* (Hedw.) B., S. et G.

All the other species have been found rarely - only in one or two sample plots or separate zones, where the environmental conditions are favourable. The swamp wood species are found only in those alder swamp woods, where the high level of moisture is characteristic also during the summer period. The characteristic indication of black alder swamp woods is a mosaic form structure with various plant communities, for example, on the stem relief there could be species that are typical for different forest ecosystems (Ek et al., 2002). But on the ground layer typical swamp species, for example, *Viola palustris* L., *Iris pseudacorus* L. (constancy class III) have been found, uncommon species : *Comarum palustre* L. (constancy class II), *Typha angustifolia* L., *Equisetum fluviatile* L. and *Menyanthes trifoliata* L. (constancy class I) were identified.

Projective coverage

The projective coverage analysis enables to draw a conclusion that the most average projective coverage (89.2%) is in the herb layer, where the next stands on S-SW side are at the age of 1-10 years. In the sample plots, where the next stands on S-SW side are at the age of 40-50 years, the average projective coverage is 76.1%. The smallest projective coverage in the herb layer (70.3%) is observed in the sample plots, where the next stands on S-SW side are at the age of 20-30 years. In the tree layer the most average projective coverage is 69.9%, where on S-SW side the stands are at the age of 40-50 years. In the sample plots, where the next stands on S-SW side are at the age of 20-30 years, the average projective coverage is 64.7%, but in the sample plots, where the next stands on S-SW side are at the age of 1-10 years, the average projective coverage is 62.4%.

In the moss layer the most average projective coverage is 49% in sample plots, where the next stands on S-SW side are at the age of 20-30 years. In the sample plots, where the next stands on S-SW side are at the age of 1-10 years, the average projective coverage is 45.8%. In the moss layer, the average

projective coverage is 35.8% in the sample plots, where the next stands on S-SW side are at the age of 40-50 years.

In comparison, the smallest projective coverage is observed in the shrub layer. In the sample plots, where the next stands on S-SW side are at the age of 1-10 years, the average projective coverage is 31.6%. The smallest projective coverage in the shrub layer (14.7%) is in sample plots, where the next stands on S-SW side are at the age of 40-50 years. The dominant species in the shrub layer is *Padus avium*, the most often observed in the sample plots of the first and third zones. The average projective coverage (%) by stands and sample plots with different age classes are shown in Figure 3.

The average projective coverage in the tree layer is 65.7%, in the shrub layer – 24.1%, in the herb layer – 78.56% and in the moss layer – 43.5%. The projective coverage (%) of vegetation indicates the location of species and composition structure in the sample plots. The availability of light in the sample plots, the composition, adaptation and structure of species in the shrub, herb and moss layers depend on the projective coverage of tree layer (Johansson, 2005). The dominant species in the tree layer is *Alnus glutinosa* that provides the soil nitrification (Rydin et al., 1999), but the 2nd common species in the sample plots *Picea abies* makes the soil acid. In the black alder swamp woods are no mono-dominant species in the herb layers, which typical mosaic structure on the ground layer and stem form micro relief promoted the diversity of species. And the projective coverage in the herb layer is not constant. The particular spatial structure and fragmentation in the habitats are adaptive for different vegetation types (Priedītis, 1999; Auniņš et al., 2010), for example, the uncharacteristic species are spreading and could be found in the sample plots. The significant threatening factor is drainage and, as a result of it, the composition of species changes (Priedītis, 1999; Auniņš et al., 2010; Johannson, 2005). Frequently occurring species are adaptive to different environmental conditions. In the first zones of sample plots, it is possible to observe species that are not typical for the forest ecosystems. This fact is an evidence for the significant impact of edge effect (Grime, 2001).

The analysis of the average projective coverage by zones enables to draw a conclusion that the 1st zones herb layer projective coverage is 78.8%, for the tree layer it is 70.7%, for the moss layer – 49.9% and for the shrub layer – 25.2%. In the 3rd zones of sample plots the average projective coverage in the herb layer is 75.8%, in the tree layer – 63.7%, in the moss layer – 35.9% and the shrub layer – 18.2%. The average projective coverage of the 5th zones of sample plots in the herb layer is 81.1%, in the tree layer – 62.7%, in the moss layer – 45% and in the shrub layer – 28.9%. The average projective coverage (%) in the sample plots by zones is shown in Figure 4.

According to the analysis of projective coverage by zones, the dominant species in the tree layer are *Alnus glutinosa* (nitrophyllous type species), *Picea abies* (boreal type species) and *Betula pubescens*. The dominant species in the shrub layer are *Padus avium* (nitrophilous type species), *Sorbus aucuparia* L. (boreal type species) and *Corylus avellana* L. (nemoral type species). The most dominant species in the herb layer is *Oxalis acetosella* (boreal type species). This species is identified in all sample plots; it is one of the most widely spread species in these habitat types. *Urtica diotica (L.)* (nitrophilous type species) is frequently found in the sample plots.

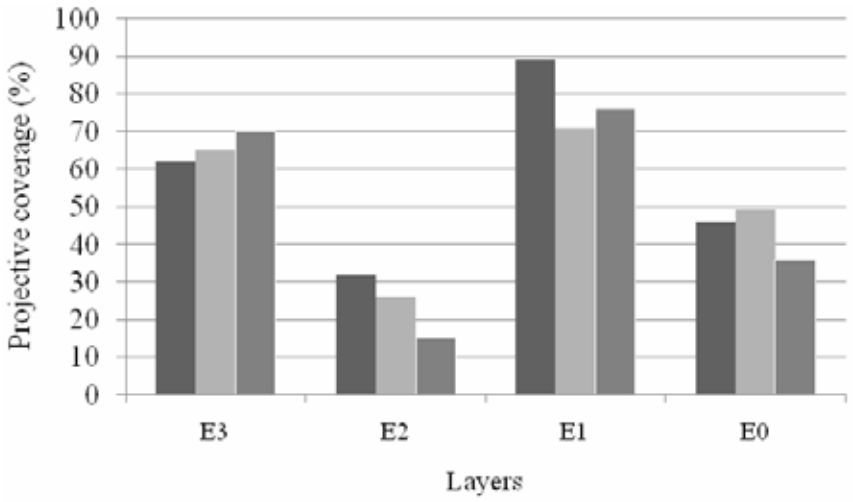

Figure 3. The comparison of projective coverage (%) by stands and within different age classes.
(■ – 1-10 years old stands; ■ – 20-30 years old stands; ■ – 40-50 years old stands;
E3 – tree layer; E2 – shrub layer; E1 – herb layer; E0 – moss layer).

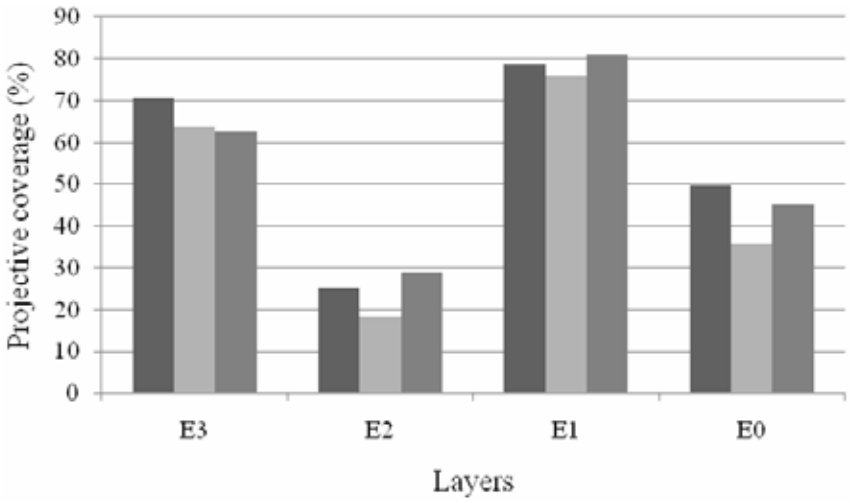

Figure 4. The average projective coverage (%) by zones.
(■ – 1st zone; ■ – 3rd zone; ■ – 5th zone; E3 – tree layer; E2 – shrub layer; E1 – herb layer; E0 – moss layer).

In the sample plots of black alder woodland the key habitat type indicator species have been found, for example, in the herb layer - *Milium effusum* L., *Solanum dulcamatra* L. and *Lysimachia vulgaris* L. (Priedītis, 1999; Auniņš et al., 2010). The most common species with average projective coverage (%) in the moss layer are *Thuidium tamariscum*, *Dicranum polysetum* Sw. and *Calliergonella cuspidata* (Hedw.) Loeske. In the moss layer the indicator species have been also found, for example, *Plagiomnium elatum* and *Climacium dendroides* (Hedw.) Web. Et Mohr.

The results of the one – way analysis of variance showed that the projective coverage (%) differences among the sample plots within different age classes of the next stands and among the zones have not been significant for the impact of edge effect on vegetation diversity (with credibility level 95%).

The impact of edge effect on the vegetation diversity is explicit in the sample plots, where the next stands on S-SW side are at the age of 1-10 years; there have been species identified that are uncharacteristic for these habitats. There is regularity among the locations of habitats. In the sample plots that are located near the roadsides or open patches, it is observed that diversity and composition of species are untypical for these habitat types (Packhman et al., 1992). Several studies have been performed to find out the impact of edge effect on the vegetation diversity; however, the results and conclusions are slightly different. In each location the assessment of the edge effect is evaluated separately, but it is more explicit, if the territory is on the edge that links different habitat types or ecosystems (Peterken, 1996). To analyze the width of edge effect and width of buffer zones establishment as an important factor is the age of next stand. As an important factor in forestry planning is the fact, that the structure of vascular plants and bryophytes depends on forest structures (Larsson, 2001), the composition of tree species and micro climate (Barrera-Lopez et al., 2007).

PCA analysis

PCA analysis shows the growth differences in black alder woodland key habitats. The ordination of species has defined the soil fertility and the gradient of moisture. The most closely by ordination of soil fertility is *Oxalis acetosella*. This species is located with mid moist and mid fertility soils. Also, *Picea abies*, *Maianthemum bifolium* and *Viola palustris dominate* closer to the soil fertility gradient.

On the right side of ordination more species, characteristic to the soil rich in nutrients, for example, *Milium effusum* and *Quercus robur* L as well as nitrophilous - *Naumburgia thyrsiflora* (L.) Rchb. on the herb layer and in a shrub layer *Alnus glutinosa* have been located. Closer to the middle point boreal forest type and meadow type species, for example, *Vaccinium myrtillus* and *Fragaria vesca* L have been identified. In the centre of ordination in the tree layer – *Picea abies*, the shrub layer – *Padus avium* and the herb layer – *Urtica dioica* have been found.

In general, all species are located quite closely to each other, which indicates demand for similar growth condition. In black alder woodland key habitats with the indicator and characteristic species (Priedītis, 1999; Ek et al., 2002) have occurred. Mostly the diversity of other species are identified in sample plots, where next stands S-SW side at the age class 1-10, for example *Cirsium arvense* (L.) Scop. (meadow type species) *Urtica dioica* L. and *Stellaria nemorum* L. (both - nitrophilous type species). Particularly, in one sample plot all 3 zones *Impatiens parviflora*- adventives species with rapid distribution has been identified. Due to the result of drainage, the soils are getting richer (Priedītis, 1999) and there is

a change in plant communities and composition of species. Due to the climate changes (the amount of nitrate has increased in atmosphere), during the last century there are changes in forest growth types; mesotrophic forests have increased (Bambe and Donis, 2008).

Conclusions

The vegetation analysis shows that the number of species and composition in sample plots in different zones are variable; particularly the influence from the edge is noticed in the herb layer. In sample plots several plant communities, especially in the 1st and 3rd zones identified as untypical species for black alder woodland habitats have been found. Several meadow type species *(Fragaria vesca, Agrostis stolonifera* L.) and also one adventives species- *Impatiens parviflora* have been identified. However, most study sites have been observed in habitats characterized by mosaic structure with indicator species: *Solanum dulcamara, Dryopteris cristata* L. A.Gray and others. In study sites vascular plant and bryophyte indicator species have been identified, as well as protected species: *Circaea lutetiana* in one site and *Plagiothecium undulatum* in three sites. The differences among the sample plots within different age classes of next stands and among the zones have not been significant for the impact of edge effect on vegetation diversity (with credibly level 95%). Black alder woodland key habitats is the import and priority protected habitat type whose preservations can be achieved in implementation of several preventative activities, for example, buffer zone creation around habitats, decrease of drainage impact and others.

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References

1. Āboliņa A. (2001) Latvijas sūnu saraksts. (The list of Latvia' bryophytes). *Latvijas Veģetācija 3*, 47–87. lpp. (in Latvian).
2. Angelstam P., Bērmanis R., Ek T., Šica L. (2005) *Maintaining forest biodiversity in Latvia's forest*, State forest service, Riga, Latvia, 36 p.
3. Aune K., Jonsson B.G., Moen J. (2005) Isolation and edge effect among woodland key habitats in Sweden: Is forest policy promoting fragmentation?, *Biological conservation 124*, pp. 89–95.
4. Auniņš A., Bambe B., Eņģele L., Ikauniece S., Kabucis I., Laime B., Lārmanis V., Rēriha I., Rove I., Rūsiņa S., Salmiņa L., Sniedze R. (2010) *Eiropas Savienības aizsargājamie biotopi: noteikšanas rokasgrāmata (Habitats of European Importance and Protected Habitats in Latvia: Manual of Determination and Methodology)*, Latvijas Dabas fonds, Riga, LV, 335 lpp. (in Latvian).
5. Bambe B., Donis J. (2008) Pakāpenisko ciršu ietekme uz meža veģetāciju (The impact of shelter – wood cuttings on forest vegetation). *Mežzinātne 17*, 48–87. lpp. (in Latvian).
6. Barera-Lopez F., Arenesto J., Williens L., Smith R.C., Marson R.H. (2007) *Fragmentation and edge effects on plant – animal interactions, ecological processes and biodiversity. The forests of Montana, Mexico and temperate South America*, CABI, Mexico, 29 p.
7. Ek T., Suško U., Auziņs R. (2002) *Mežaudžu atslēgas biotopu inventarizācija (Woodland Key Habitat Inventory in Latvia),*Valsts meža dienests, Riga, Latvia, 76 lpp. (in Latvian).
8. Gavrilova G., Šulcs V. (1999) *Latvijas vaskulāro augu flora. Taksonu saraksts* (Flora of Vascular Plants in Latvia. List of Taxa.), Latvijas Akadēmiskā bibliotēka, Riga, Lavia, 136 lpp. (in Latvian).
9. Grime P.J. (2001) *Plant Strategies, Vegetation Processes and Ecosystem Properties*, John Wiley and Sons Ltd, London, UK, 417 p.
10. Hallanaro E.L., Pylvanainen M. (2001) *Nature in the Northern Europe*, Nordic council of ministers Nord., Copenhagen, Denmark, 350 p.
11. Johansson T. (2005) *Management Manual for Woodland Key Habitats in Latvia*, State Forest Service, Riga, LV, 37 p.
12. Larsson T.B. (2001) *Biodiversity evaluation tools for European forests*, Blackwell science, Oxford, UK, 240 p.
13. Madžule L., Brūmelis G. (2008) Ecology of Epixlic Bryophytes in Eurosiberian Alder Swamps of Latvia. *Acta Universitatis Latviensis, 745*, Riga, Latvia, pp. 103–114.
14. Muller – Dombois D., Ellenberg H. (1974) *Aims and Methods of Vegetation Ecology*, John Wiley and Sons, New York, US, 574 p.

15. Orczewska A. (2009) The impact of former agriculture on habitat conditions and distribution patterns of ancient woodland plant species in recent black alder (*Alnus glutinosa* (L.) Gaertn.) Woods in south – western Poland. *Forest ecology and management 258*, pp. 794–797.
16. Packhman J.R., Harding D.J.L., Hilton G.M., Stuttard R.A. (1992) Ecology of Woodlands and Forests. *Kluwer Academy publishers*, Dordrecht, Netherlands, pp. 68–87.
17. Pakalne M., Znotiņa V. (1992) *Vegetācijas klasifikācija: Brauna-Blanke metode (Vegetation Classification: Braun – Blanque Method)*, Riga, Latvia, 32 p. (in Latvian).
18. Peterken G.F. (1996) *Natural woodland. Ecology and Conservation in Northern Temperate Regions*, Cambridge University press, Cambridge, UK, 486 p.
19. Priedītis N. (1993) *Latvijas purvainie meži un to aizsardzība (Swamp Forests of Latvia: Status and Conservation)*,WWF, Riga, Latvia, 180 p.
20. Priedītis N. (1997) Alnus Glutinosa – dominated wetland forests of the Baltic region: community structure, syntaxanomy and conservation. *Plant Ecology 129*, pp. 49–50.
21. Priedītis N. (1999) *Latvijas mežs: daba un daudzveidība (Latvian Forest: Nature and Diversity)*, WWF, Riga, Latvia, 209 lpp. (in Latvian).
22. Priedītis N. (2002) Evaluation Frameworks and Conservation System of Latvia Forests. *Biodiversity and Conservation 11*, pp. 1361–1365.
23. Rydin H., Snoeeijs P., Diekmann M. (1999) Swedish Plant Geography, Opulus Press AB, Uppsala, Sweden, 232 p.
24. Tabaka L. (2001) *Latvijas flora un veģetācija: Zemgales ģeobotāniskais rajons (Flora and Vegetation in Latvia: Geobotanical Region Zemgale)*, Latvijas Universitāte, Riga, Latvia, 98 p. (in Latvian).
25. Wulf M. (2003) Preference of plant species for woodlands with differing habitat continuities. *Flora 198*, pp. 440–460.

THERMAL WEED CONTROL IN NORWAY SPRUCE (*PICEA ABIES* (L.) H.KARST.) NURSERY

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Abstract
Growing of economics and new technologies has caused the environment pollution and more intensive use of natural resources. The principles of stable and balanced forestry became more and more important. Ecologization forests economy directly and indirectly impacts environment, water, air, landscape. It is not allowed to use chemicals in ecological farms. In Lithuania the number of ecological farms is growing that is why the new effective ecological methods are needed to protect seedlings from weeds. Alternative to mechanical control of weed is to use high temperature. In ecological farms weed control after sowing time is pursued in mechanic, and recently in thermal way. In thermal weed control the surface of soil remains mechanically undisturbed, the roots of cultural plants remain undisturbed, too. These features are very important in forest nurseries, where different kinds of tree species are growing. Seedlings are very small at the beginning of growing, so mechanical weed control is difficult. Thermal weed control could be a good alternative. Comparable data of 2009-2011 thermal weed control research in Norway spruce (*Picea abies* (L.) H. Karst.) nursery is given. The efficiency of destroyed 16 weed sorts using thermal and mechanical ways of weed control is given. Thermal weed control for short age weeds is 20.3% more effective in comparison with mechanical way. Mechanical way is 35.2% more effective for perennial weeds. It was detected that in order to control weeds of different growth stages, it is necessary to use different treatment time of damp water stream.
Key words: thermal weed control, weeds, technology, Norway Spruce.

Introduction

In Lithuania as well as in all European Union general politics of agriculture and forest sectors is oriented to ecological farming. The main object of ecological farming is to improve soil texture, reduce pollution of heavy metals, and increase stocks of humus and nutrients in the soil. Numbers of ecological farms are growing. In the ecological farms weeds after sowing are exterminated by physical and mechanical processes such as mechanical removal, harrowing and inter-row cultivation. Roots of cultural plants grown are injured when mechanical weeding is carried out. Mechanical injuries of the over–soil parts of the plants are also unavoidable, and it reduces productivity (Lisek, 2001).

More significant attention is given to the thermal methods. Process of thermal methods could be different various temperature environments. Application of thermal weed control processes increases and utilization of flaming by gas, hot water and damp water stream procedures spreads out rapidly (Ascard, 1995; Sirvydas et al., 2003).

Damp water stream is ecological high temperature environment that can fully replace pesticides. In the working environment temperature is 100 °C (Gimbutis, 1993). Process of heat transmission is very intensive, stream condensation takes place on the weeds surface and the heat is given. Devices of damp water stream are very effective (Gimbutis, 1993). The environments of high temperature water stream do not allow resisting for the live organisms.

Thermal weed extermination is based on the thermal energy exchanges and balance in high temperature medium. With the plant tissue temperature raised to over 58 °C, the lethal outcome of the weed plant is assured. The biological struggle of the plant against the unusual effect by high temperature medium takes place, duration of which depends upon mass of plant tissues involved and the thermodynamic properties of the thermal medium applied. Plants with smaller biometric dimensions in damp water stream reach their value of the lethal level in 0.5–2 s. Plants with greater biometric dimensions during the same time undergo thermal stress. As a result, it increases productivity (Vasinauskiene, 2004). Data in literature on extermination of various weed plants in high temperature media were not found.

The aim of the study is to establish efficiency of mechanical and thermal weeding and the sensitivity of weeds to high temperature damp water stream medium.

Materials and Methods

Analysis of weeds was investigated in the nursery of Šiauliai Forestry Enterprise. Species structure and number of weeds was detected in the experimental patches (0.2 cm x 0.25 cm) which were put on the Picea abies seedlings according to their nutrition area (Figure 1). Experimental patches were put as it is noted in the methodology (Raudonis, 2009). The experiment was repeated six times.

In the first variant weeds were removed manually 3 times. This is the traditional way of weeding. For the first time weeds were removed just after mass shooting in the stage of appearance of the first to second leaves. Weeds were removed the second and

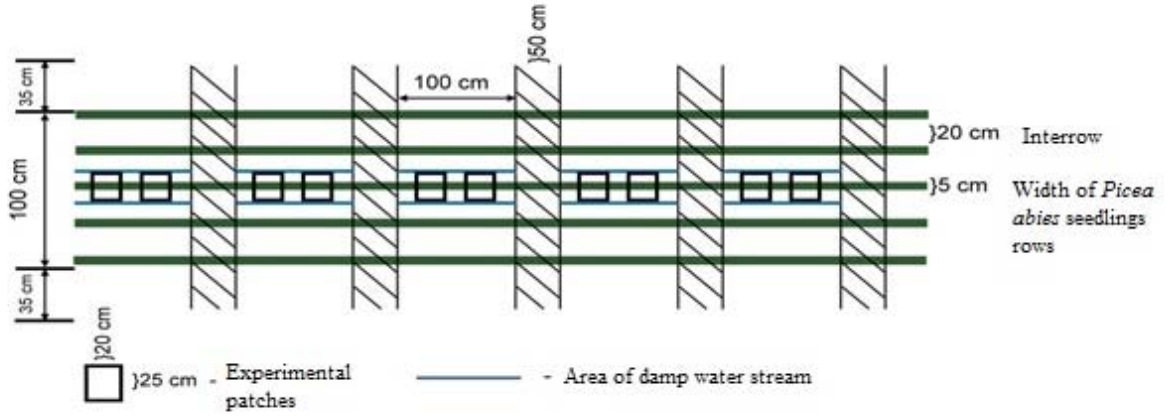

Figure 1. Experimental patches of thermal weed control.

the third time again at the same stage of appearance of the first to second leaves. In the second variant weeds were exterminated using damp water stream two times during the vegetative season. Duration of the thermal exposure was 2 seconds. Thermal weed extermination was carried out in the entire basic patch with protection for Picea abies seedlings from the exposure to damp water stream. For the first time weeds are removed just after mass shooting in the stage of appearance of the first to second leaf. The damp water stream was used for the second time shooting in the stage of appearance of the first to second leaf. Before weed thermal control procedures in all experimental patches weeds were counted and in each patch in four places having area of 0.25 m² sort composition analysis of weeds was carried out. Weed reduction percent values according to weed groups were established for different weed control technologies.

For the Picea abies seedlings area of 2011 remaining weeds were counted on the fourth day after extermination and sort composition was not determined. Weeds were exterminated just sprouting in the seed-lobe growth stage.

Results and Discussion

According to the analysis of weeds thermal control, it was detected that in order to control weeds of different growth stages it is necessary to use different treatment time of damp water stream (Hanson and Ascard, 2002; Melander and Hanson, 2007; Sivesind et al., 2009).

On purpose to control weeds, the treatment of damp water stream is most effective when weeds are in the stage of 1-3 leaves (Vasinauskienė, 2004; Čekanauskas, 2007). If this treatment is done later, the destruction of weeds is more difficult because of changes in their morphological structure. By the morphology and spreading of warmth through the plant tissues, thermally controlled weeds are divided into three groups: 1 – easily controlled by damp water stream (Chenopodium album, Stellaria media, Veronica, Galinsoga, etc.), 2 – hardly controlled by damp water stream annual meadow weeds (Echinochloa crus-galli L., Poa annua, etc), 3 - hardly controlled by damp water stream rosette weeds (Capsella bursa-pastoris, Plantago major, Taraxacum, etc.).

Investigations of thermal weed control using various weed extermination technologies have shown that different sorts of weeds are destroyed to different extent. In 2009−2010 weeds Stellaria media L. Vill., Chaenorhinum minus (L), Galinsoga parviflora were destroyed completely (up to 100%) while after the simple mechanical removal on average 3.27 to 0.7 unit m^{-2} weeds remained though disturbed. Thermal weed control leaves the soil structure unchanged without activating new weed sprouting. Weed extermination efficiency for separate weed control technologies is presented in Table 1.

In 2009−2010 experiments 16 kinds of weeds prevailing in number were investigated. 36.4% of them were perennial and 64.6% were short−lasting weeds. Their biological properties determine the extermination procedures of short age and of monocotyledonous and perennial weeds using damp water stream (Figure 2).

Survey of the three year period data for harvesting period (Figure 2) shows that mechanical extermination left on the average 31.9% of weeds to grow, while extermination using damp water stream left 5.9% of weed plants not destroyed. Thermal extermination of short age weeds using damp water stream is effective enough. We can see from (Figure 2) that short age monocotyledonous weeds (Echinochloa crus-galli (L.) Pal. Beauv., Poa annua (L.)) have greater resistance to damp water stream medium. Efficient extermination of monocotyledonous weeds is determined mainly by their biological properties and growth stages. Extermination of monocotyledonous weeds is most successful in the growth stages of sprouting-first leaf. Count of weed numbers during Picea abies seedlings harvesting time showed that weed extermination left

31−44% of perennial weed plants undestroyed, while thermal extermination using damp water stream left 23−65% of them undestroyed (Figure 3). Thermal weed extermination destroys only the over−soil part of the weed plant, and this influences the revival of the perennial weed plants. In 2009 experiments among weed species Sonchus arvensis L., and Elytrigia repens (L.) prevailed in number, and this influenced great variation of weed quantities (unit m^{-2}).

Table 1

Number of weed plants (unit m^{-2}) during harvesting after mechanical and thermal weeding

Weed species	Mechanical weed control			Thermal weed control		
	2009	2010	2011	2009	2010	2011
	$\overline{x} \pm S_{\overline{x}}$					
Chenopodium album.	3.66±0.9	0.98±0.46	4.74±1.02	1.35±0.50	0.00±0.00	1.2±0.47
Atriplex patula	1.46±0.57	38.07±2.89	15.40±1.84	0.30±0.47	0.75±0.37	0.00±0.00
Stellaria media	1.65±0.61	1.72±0.62	3.27±0.85	0.15±0.37	0.00±0.00	0.00±0.00
Veronica Spp.	1.46±0.57	2.20±0.69	1.72±0.62	0.00±0.00	0.75±0.37	0.75±0.37
Chaenorhinum minus	1.65±0.61	0.7±0.40	0.70±0.40	0.30±0.74	0.00±0.00	0.00±0.00
Galinsoga parviflora	1.46±0.57	0.83±0.43	1.93±0.65	0.00±0.00	0.00±0.00	0.00±0.00
Matricaria inodora	0.91±0.45	6.6±1.21	0.98±0.46	0.00±0.00	7.95±1.20	4.95±0.95
Echinochloa crusgalli	3.11±0.83	7.43±1.28	8.53±1.38	1.35±0.95	10.20±1.36	8.55±1.24
Poa annua	8.06±1.33	6.40±3.75	43.24±3.08	6.30±4.86	16.95±1.75	8.22±3.84
Capsella bursa pastoris	1.46±0.57	6.84±1.23	4.13±0.96	1.20±1.23	1.35±0.50	1.20±0.47
Equisetum arvense	0.91±0.45	2.20±0.69	14.92±1.82	0.15±0.37	1.20±0.47	3.60±0.80
Mentha arvensis	1.46±0.57	1.72±0.62	1.93±0.65	0.45±0.76	0.00±0.00	3.00±0.74
Plantago major	1.46±0.57	14.18±1.77	19.80±2.09	0.15±0.37	3.00±0.74	4.35±0.88
Elytrigia repens	1.65±0.61	4.13±0.96	0.98±0.46	11.40±8.13	8.55±1.25	3.15±0.76
Carsium arvense	2.20±0.69	3.92±0.92	17.84±1.98	6.00±5.54	2.55±0.68	10.35±1.37
Sonchus arvensis	5.86±1.13	5.23±1.07	9.78±1.46	10.80±5.89	9.75±1.32	10.35±1.37

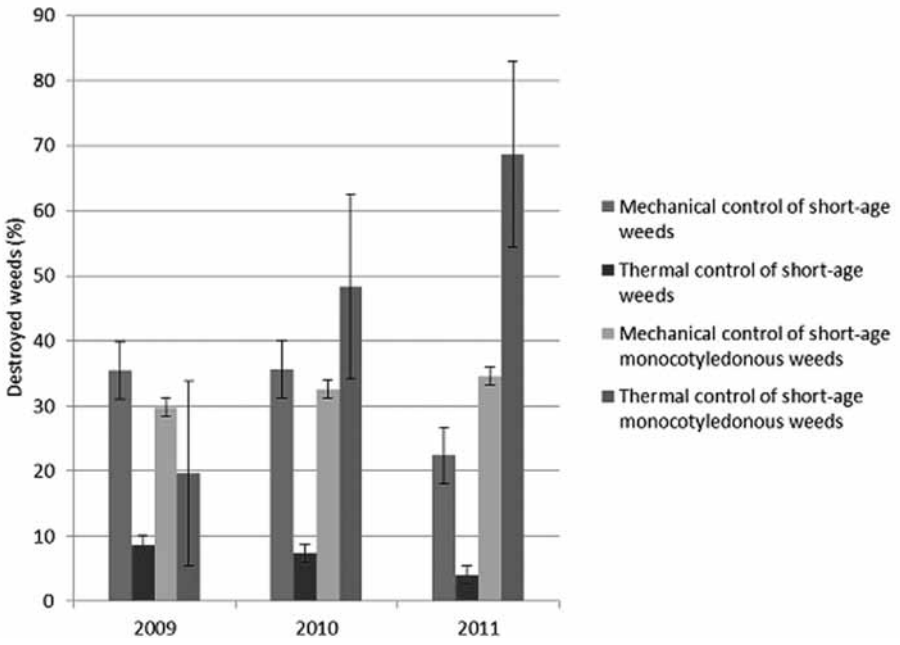

Figure 2. Percentage of destroyed weeds for different weed thermal control technologies.

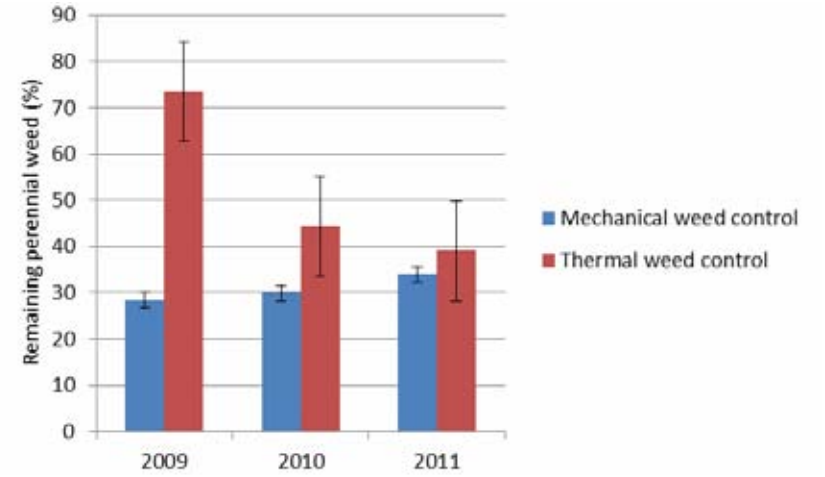

Figure 3. Percentage of remaining perennial weeds after mechanical and thermal weed control procedures.

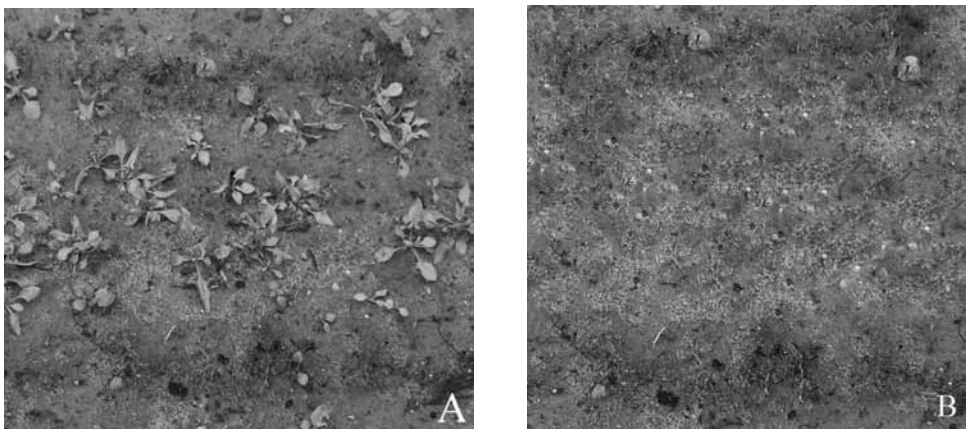

Figure 4. Thermal weed control: A–view before weed extermination, B– view after weed extermination.

In 2011 thermal weed control was carried out in the Picea abies seedlings area 10 days after sowing. Weeds were exterminated during the sprouting phase. In case when mechanical weed control has been applied, 65.39% of weeds were destroyed, while after thermal control procedures 99.02% of weeds were destroyed (Figure 4).

During mechanical weed extermination in most cases they are not exterminated in close proximity of the culture plant. During thermal extermination weeds are flushed by damp water stream completely, and they are exterminated even in the closest proximity of the plant.

Conclusions

1. Thermal weed extermination is more advantageous if compared with mechanical one in properly cultured soils.
2. Thermal weed control for short age weeds is 20.3% more effective in comparison with mechanical way. Mechanical way is 35.2% more effective for perennial weeds.
3. Thermal weed extermination by damp water stream is applied at the shooting stage. Shooting weeds are destroyed in the closest proximity of the cultured plant.
4. In the crop area of Picea abies grown by seedlings during vegetative season weeds should be exterminated two times. Duration of exposure to damp water stream media is 2 seconds.

References

1. Ascard J. (1995) Thermal Weed control by Flaming. Department of Agricultural Engineering. pp. 1–37.
2. Čekanauskas S. (2007) Aukštatemperatūrės aplinkos veiksniai termiškai naikinant piktžoles (High-temperature thermal environmental factors in weed). Akademija, 100 p. (in Lithuanian).
3. Hanson D., Ascard J. (2002) Influence of developmental stage and time of assessment on hot water weed control. Weed Research 42, pp. 307–316.

4. Gimbutis G. (1993) Šiluminė technika. (Thermal technology). Vilnius, LT, 334 p. (in Lithuanian).
5. Lisek J. (2001) Ochrona plantacji truskawek przed chwastami. Intensyfikacja produkcji truskawek. Skierniewice (Strawberry plantation protection against weeds. Intensification of strawberry production). pp. 84–88. (in Polish).
6. Melander A., Hanson D. (2007) Weeds are not just weeds. Conference on Sustainable Weeds Management on Hard Surfaces in Urban Areas. University of Copenhagen, Denmark, pp. 221–229.
7. Raudonis S. (2009) Mokslinių tyrimų metodika (Research methodology). Akademija, pp. 119. (in Lithuanian).
8. Sirvydas A., Lazauskas P., Vasinauskienė R., Kerpauskas P. (2003) Thermal weed control by water steam. European Weed Research Society. The 5th EWRS Workshop on Physical and Cultural Weed Control, Pisa, Italy, pp. 253–262.
9. Sivesind E.C., Leblanc M.L., Cloutier D.C., Seguin P., Steward K.A. (2009) Weed response to flame weeding at different developmental stage. Weed technology 23, pp. 438–443.
10. Vasinauskienė R. (2004) Terminės aplinkos poveikio augalams tyrimai ir agrotechnologinis įvertinimas. (Thermal environment impact on the plants and evaluation of agrotechnology). Akademija, pp. 99. (in Lithuanian).

BELOW-GROUND BIOMASS PRODUCTION IN YOUNG STANDS OF SCOTS PINE (*PINUS SYLVESTRIS* L.) ON ABANDONED AGRICULTURAL LAND

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Abstract
Tree roots take up a high proportion of forest biomass, and nowadays we use different methods to estimate the root biomass. Methods vary greatly due to the different studies and different excavation methods used. In the summer 2010, a study of the below-ground biomass of young Scots pine *Pinus sylvestris* L. stands was carried out in central Latvia. In this paper, different below-ground biomass fractions data of 10 sample trees from the abandoned agricultural land plantations were approximated by allometric functions depending on tree stem diameter at breast height 1.3 m (DBH). The main objective was to determine the average below-ground biomass and approximated below-ground biomass fractions by allometric functions depending on tree DBH of young stands of Scots pine on abandoned agricultural land. Our regressions offer good overall approximations of the data. DBH – stump, coarse root and small root and total biomass regressions were highly significant ($p<0.001$). The most substantial part of total below-ground biomass was from stumps (45%). The smallest shares of the biomass were coarse roots 38% and small roots 16%. The largest portion (52%) of the total fine-root biomass of 12- and 14-year-old Scots pine stands was located at a depth of 0–10 cm, decreasing in deeper mineral soil layers. Total dry (DM) below-ground biomass including fine-root biomass was 19.0 ±5.2 t DM ha^{-1}.
Key words: Scots pine, Root biomass, Agricultural land, Sapling stands, Regression equation.

Introduction

Root biomass is an important part of the biosphere and can take up to 30% of the total above-ground biomass (Grier et al., 1981; Hoffmann and Usoltsev, 2001). Tree growth in boreal forests is generally limited by the availability of nutrients, especially nitrogen. Therefore, the below-ground compartments are responsible for the acquisition of scarce soil resources. The root systems provide trees with physical support and the ability to capture resources essential for growth and reproduction (Gautam et al., 2003).

Accurate quantification of below-ground carbon stocks in forests is critical for effective predictions of how future climate change will impact global carbon dynamics. However, the development of forest carbon budget models has historically been restricted by the lack of species and site-specific estimates of below-ground biomass (Brassard et al., 2011). Root biomass production is important for modeling carbon cycling, but its calculation has been dependant on the available data.

Gathering data on root biomass distribution is a very drudgery process. It includes root excavation, washing, sieving, separating gathered material into species and diameter classes and also biomass weighing (Polomski and Kuhn, 1998). Root distribution may be very heterogeneous and extensive due to the rocks and impenetrable layers of the soil. It may depend on many factors such as tree species, influence of water supply and ground water table (Hoffmann and Usoltsev, 2001). Very often data is reported per unit of forest area only, making these data unusable for modeling based on individual tree root biomass (Santantonio et al., 1977; Haland and Braekke, 1989).

Relatively few studies are dealing with both root diameter and rooting depth for individual trees. Their findings are often hard to compare due to several reasons (Jenik, 1971; Haland and Braekke, 1989). Stump biomass which is very important part of below-ground biomass is not uniformly defined, separately from total biomass, or ignored completely, and the size of root biomass classes are defined significantly differently (Hoffmann and Usoltsev, 2001).

In this study, the main objective was to determine the average below-ground biomass production in different fractions and develop DBH – stump, coarse root and small root biomass equations for young trees of Scots pine.

Materials and Methods

Study area

The research was carried out in two young stands of Scots pine (*Pinus sylvestris* L.), established in central Latvia, Ozolnieki and Iecavas regions, approximately 25 km east of Jelgava. One of the closest meteorological stations is located in Jelgava. The study area has a temperate climate, moderately warm and dry with 3 to 4 months long vegetation period. The average annual precipitation for Jelgava (period 2000 – 2010) is 584 mm and average annual temperature is 6.9 °C. The prevailing site type of the region is well drained agricultural land.

Experimental stands

Our research of below-ground biomass production was carried out in two planted Scots pine stands on abandoned former agricultural land. The average age of the stands was 12 and 14 years. The spacing in plantations was from 1.0 m between rows and from 2.0 m within rows. Stand density was between 2145 and 2925 trees per ha in the plantations (Table 1). One experimental sample plot (500 m^2) in each stand was established in the summer 2010. The stem diameter at breast height 1.3 m (DBH) and the height of all trees were measured in each sample plot.

The stands were situated on a similar site and soil type. In both Scots pine stands there was sandy loam soil, with a relatively thin humus layer, but saturated with nutrients. The site type according to classification is *Hylocomiosa* (Bušs, 1981).

Table 1

Characteristics of studied plantations

Characteristics	Stand age (years)	
	12	**14**
Plot area, m^2	500	500
Numbers of trees ha^{-1}	2145	2925
Mean diameter, cm	11.2	10.3
Mean height, m	7.7	8.2
Basal area, m^2 ha^{-1}	21.0	24.3
Stand volume m^3 ha^{-1}	92.2	115.4

Sample tree selection

The total root system of 10 sample trees (5 in each sample plot) was excavated, washed, divided into diameter classes and weighed in the summer of 2010. Trees were selected for excavation using systematic random technique. We selected only healthy, undamaged trees within the DBH range (one minimal, three average and one maximal sample tree per each plot) and with average tree height.

Coarse root, small root and stump sampling

Root systems were excavated, washed free of soil using high pressure water, and the entire root system was divided into diameter classes and weighed on site using a hand scale. To have more accurate root biomass determination, we divided all roots in two diameter classes:

- small roots (Ø 2 – 20 mm);
- coarse roots (Ø > 20 mm) (Ohashi et al., 2007).

We included also the stump part in below-ground biomass; both the above-ground (beginning of the stem) and below-ground parts. With the latter we understand monolithic part that was not otherwise differentiated (Liepa, 2005).

Fine root sampling

Fine root sampling was conducted in August 2010. Fine roots are generally defined as non-woody, small-diameter roots (Nadelhoffer and Raich, 1992), but there is no established convention defining the diameter size range of fine roots (Fogel, 1983). In this study, roots smaller than 2 mm were regarded as fine roots. The soil core sampling method was used to collect the fine roots (diameter ≤ 2.0 mm). Twenty soil cores (volumetric samples 100 cm^3 and core diameter 50 mm) per sampling were randomly taken in both sample plots for the determination of fine-root biomass. The soil cores were divided into five layers by depth: 0–10 cm, 11–20 cm, 21–30 cm, 31–40 cm and 51–60 cm of the mineral soil.

Laboratory analyses

To determine the dry root weight of each tree root system, we randomly selected fresh root samples for each diameter classes and stump. The samples were placed in polyethylene bags, transported to the laboratory and weighed. In the laboratory, samples were dried to constant mass at 105 °C, and weighed. The fresh to dry weight ratios were then used to calculate dry weight for each below-ground fraction of the tree.

Fine root samples were placed in polyethylene bags, transported to the laboratory, and stored in a refrigerator at 4 °C until the analysis. In the laboratory, fine roots were washed and separated into Scots pine roots and roots of other plants. Roots with diameter greater than 2 mm were excluded from the analysis.

Data analysis

Single power regression models that related stump, coarse root, small root and total root biomass to DBH and height were developed for both stands (Eq. 1):

$$Y = b_1 \times X^{b_2} \quad , \qquad (1)$$

where Y is root fraction biomass (kg), X is DBH (cm) or height (m), and b_1 and b_2 are coefficients.

Descriptive statistics were use for all below-ground fractions.

Results and Discussion

Brassard et al. (2011) showed that the equations developed on the stand level of several above-ground attributes including DBH allow biomass and carbon budget models to characterize below-ground dynamics more accurately using readily available above-ground metrics. Usoltsev and Vanclay (1993) demonstrated that total root biomass could be approximated by function of diameter at breast height, with coefficients of determination of 0.956. Results of our study give evidence of close correlation between root biomass

and DBH (Figure 1), as shown also by Usoltsev and Vanclay (1993). Coefficient of determination for stump biomass in our case was 0.892, for small roots 0.851, for coarse roots 0.939 and for total biomass 0.917. Relationship between DBH and root biomass is clearly strong; therefore, this relation can be used for biomass equations.

The regression coefficients for each model are reported in Table 2. Fitted equations have the form $Y = b_1 * X^{b2}$, were y is root biomass fraction (kg), X is DBH (cm), b_1 and b_2 *are* coefficients. In Table 2 we presented regression coefficients for allometric equations relating stumps, coarse roots, small roots and total biomass to DBH in young Scots pine stands. DBH – stump, coarse root, small root and total biomass regressions were highly significant ($P < 0.001$), with correlation coefficient ranging from 0.852 to 0.926.

Hoffmann and Usoltsev (2001) stated that height turned out to be a better prediction than DBH for tree roots, resulting in the allometric equations. In our

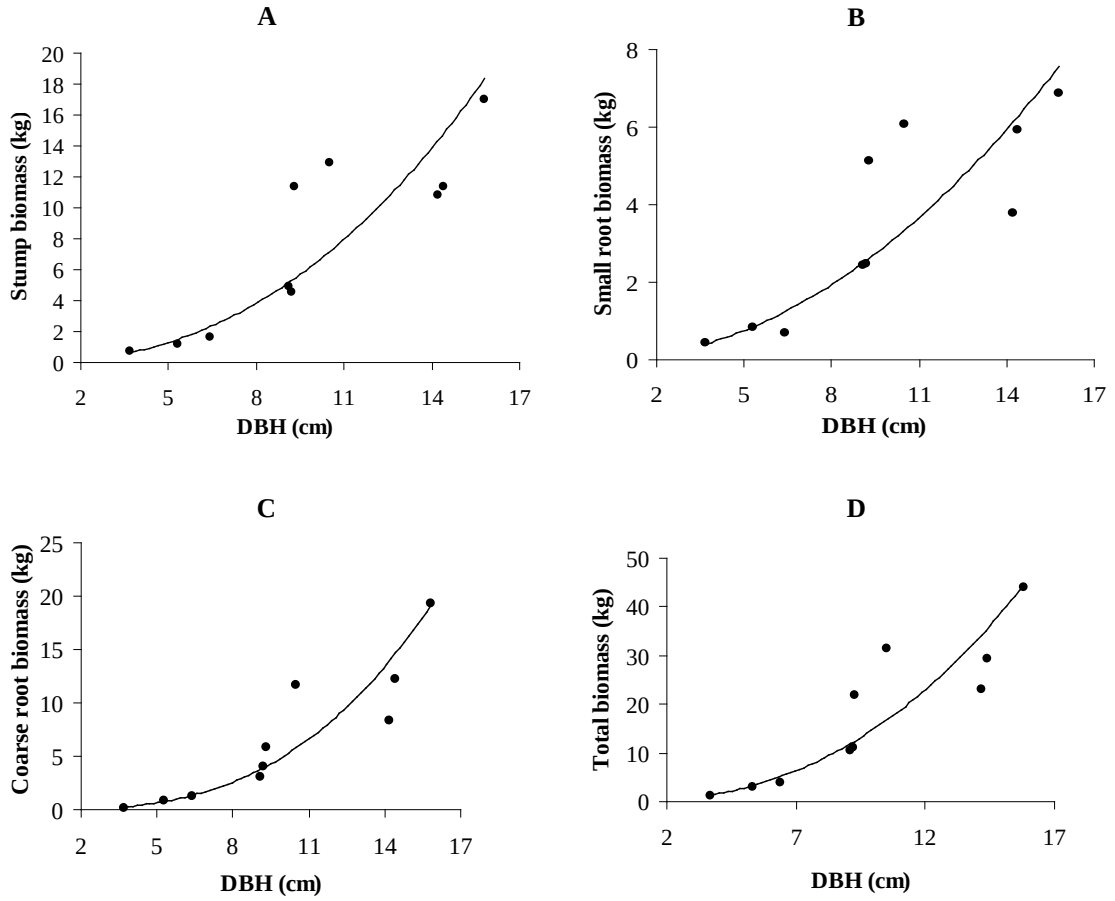

Figure 1. Relationship between DBH and (A) fresh stump biomass, (B) fresh small root biomass, (C) fresh coarse root biomass, and (D) fresh total biomass.

Table 2

Regression coefficients for allometric equations describing relation between below-ground fractions and tree DBH

Below-ground fractions	Number of tree	DBH range	b_1	b_2	R^2	P	MSE	SEE
Stumps*	10	5.3 – 15.8	0.032	2.300	0.892	< 0.001	0.157	0.396
Coarse roots*	10	5.3 – 15.8	0.060	2.943	0.939	< 0.001	0.137	0.370
Small roots*	10	5.3 – 15.8	0.030	2.004	0.851	< 0.001	0.171	0.414
Total*	10	5.3 – 15.8	0.060	2.392	0.971	< 0.001	0.127	0.356

MSE = mean square of the error
SEE = standard error of the estimate of the regression
* fresh biomass

Table 3

Regression coefficients for allometric equations describing relation between below-ground fractions and tree height

Below-ground fractions	Number of tree	Height range	b_1	b_2	R^2	P	MSE	SEE
Stumps*	10	5.9 – 10.3	0.005	3.281	0.236	> 0.05	2.744	1.053
Coarse roots*	10	5.9 – 10.3	0.0001	4.924	0.342	> 0.05	6.180	1.218
Small roots*	10	5.9 – 10.3	0.009	2.640	0.091	> 0.05	1.777	0.966
Total*	10	5.9 – 10.3	0.006	3.562	0.173	> 0.05	3.234	1.059

MSE = mean square of the error
SEE = standard error of the estimate of the regression
* fresh biomass

study we obtained different results than Hoffmann and Usoltsev, and we must conclude that DBH was a better predictor of different below-ground biomass fractions than height in our study (Table 3). DBH – below-ground biomass models had consistently higher R^2 than height – below-ground biomass models for all biomass fractions. Height – stump, coarse root and small root and total biomass regressions were not significant ($p>0.05$), with correlation coefficient ranging from 0.242 to 0.301.

The largest share (around 45%) of total below-ground biomass in young Scots pine stands was from stumps. The smallest shares of the biomass were in coarse roots and small roots - 38% and 16%, respectively. Total dry root biomass on abandoned agricultural lands in young stands of Scots pine is 14.6±5.1 t ha^{-1}, including stump biomass 6.6±2.2 t DM ha^{-1}, coarse root biomass 5.6±1.0 t DM ha^{-1} and small root biomass 4.9±0.7 t DM ha^{-1} (Figure 2). Results showed that all root fractions were developed evenly, and such root biomass structure development model is normal for young stands. Comparing our data with the literature data on grey alder (*Alnus incana* (L.) Moench), which is one of the most typical tree species on abandoned agricultural land in Latvia, we found out that DM below-ground biomass production in 10-year-old grey alder stands is more than 1.6 times less (Uri et al., 2008) than results from our study.

Comparing both stands, no significant differences (Table 4) between below-ground biomass parts were detected. Older stand produced more biomass than the younger one, but statistically the difference was not significant and for calculations both stands can be combined together.

Table 4

Average below-ground biomass of 12- and 14-year-old Scots pine stands

Stand age	Biomass $\overline{x} \pm s_{\overline{x}}$		
	Stumps*	Coarse roots*	Small roots*
12 years	5.7 ±2.9	5.7 ±3.5	2.6 ±1.2
14 years	9.4 ±2.1	7.8 ±2.1	4.3 ±1.0
p-value	0.32	0.60	0.27

*fresh biomass

The amount of fine-root biomass varies between soil layers. The largest part of the Scots pine fine roots

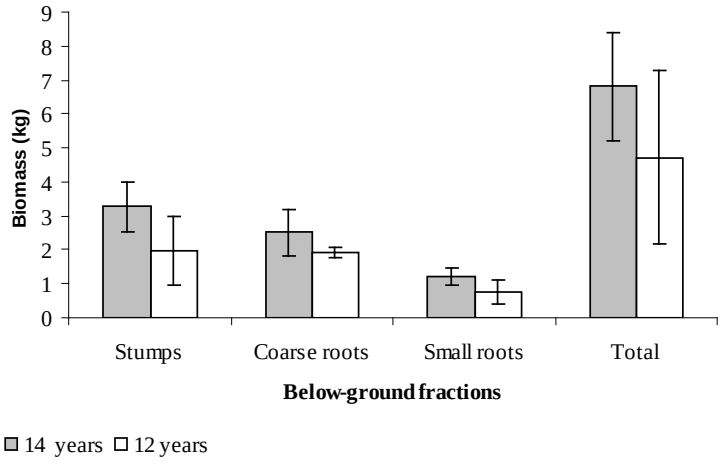

Figure 2. Mean dry biomass in different below-ground fractions. Standard error values are shown in error bars.

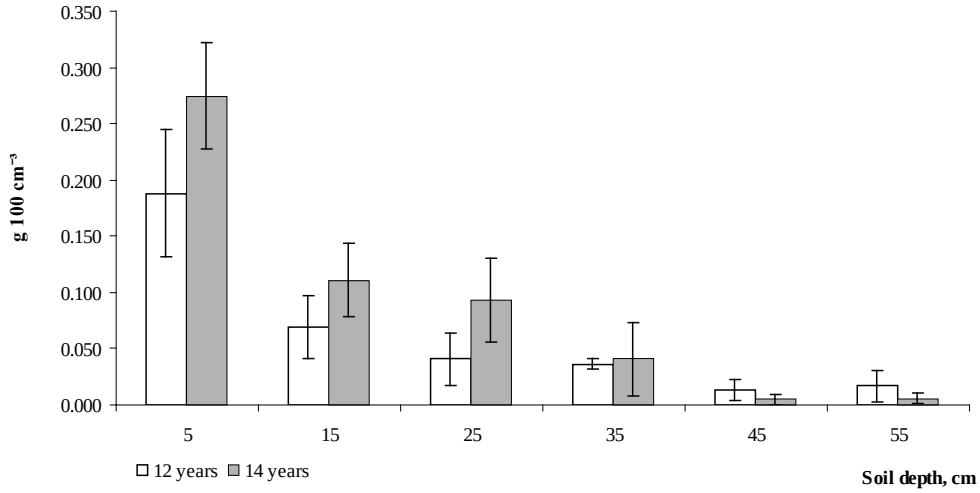

Figure 3. Comparison of fine-root biomass in different soil depths of 12- and 14-year-old Scots pine stands. Standard error values are shown in error bars.

(46%) is reported to be found in the upper mineral soil layer (Helmisaari et al., 2002). There is normally a significant distribution of fine-root biomass in the top soil layers, decreasing at greater soil depth (Claus and George, 2005; Makkonen and Helmisaari, 1998; Helmisaari et al., 2002).

In our study the value of fine-root biomass was 1.8 ±0.5 t ha^{-1} (52%) in 12-year-old and 2.7 ±0.4 t ha^{-1} in 14-year-old (52%) stand in the upper mineral soil (0–10 cm), which is nearly equal to the fine root biomass range reported by other authors (Trettin et al., 1999). Results showed a clear relation between fine-root biomass and the depth of the mineral soil layer, coefficient of determination R^2 being equal to 0.89. The largest part of fine-root biomass was located at a depth of 0–10 cm and decreased in deeper soil layers (Figure 3).

Between the soil layers and average fine-root biomass in the Scots pine stands there were significant differences ($p<0.05$). The largest distribution of fine-root biomass in soil layer 0–60 cm was found in the older stand (14-year-old) – 5.3 ±1.6 t DM ha^{-1}, but in the younger stand (12-year-old) the value was 3.6 ±1.5 t DM ha^{-1}. The studied stands were of the same age class but with different densities (see Table 1). The amount of biomass correlates with tree density per ha and describes its significant differences between both stands.

In our study, the object's total below-ground biomass including fine-root biomass was 19.0 ±5.2 t DM ha^{-1}. Regarding our results, we must agree with the other researchers who state that below-ground biomass is an important part of the tree, and plays a significant role for carbon budget modelling and tree development (Brassard et al., 2011).

Conclusions

1. Below-ground biomass fractions were approximated by function of DBH, with coefficients of determination for stump biomass 0.892, small roots 0.851, coarse roots 0.939 and total biomass 0.917, respectively.
2. DBH is a better predictor for different below-ground biomass fractions than tree height.
3. The vertical distribution of fine root biomass in the studied Scots pine stands decreased with increased soil depth.
4. The largest part (52%) of the fine-root biomass was located in the upper mineral soil layers (0–10 cm).
5. Total below-ground biomass including fine-root biomass was19.0 ±5.2 t DM ha^{-1}.

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References

1. Bušs K. (1981) *Meža ekoloģija un tipoloģija* (Forest Ecology and Typology). Zinātne, Rīga, 68 lpp. (in Latvian).

2. Brassard B.W., Chen Y.H., Bergeron Y., Pare D. (2011) Coarse roots biomass allometric equations for *Abies balsamea, Picea marine, Pinus banksina*, and *Populus tremuloides* in the boreal forest of Ontario, Canada. *Biomass and bioenergy*, 35, pp. 4189–4196.
3. Claus A., George E. (2005) Effect of stand age on fine-root biomass and biomass distribution in three European forest chronosequences. *Canadian Journal of Forest Research*, 35, pp. 1617–1625.
4. Fogel R. (1983) Root turnover and productivity of coniferous forest. *Plant and Soil*, 71, pp. 75–85.
5. Gautam K.M., Mead J.D., Frampton M.C., Clinton W.P., Chang X.S. (2003) Pinus radiate in a sub-humid temperate silvopastoral system: modelling of seasonal root growth. *Forest Ecology and Management*, 182, pp. 303–313.
6. Grier C.C., Vogt K.A., Keyses M.L, Edmonds R.L. (1981) Biomass distribution and above-and-below-ground production in young and mature *Abies amabilis* zone ecosystems of the Washington Cascades. *Can. J. For. Res*, 11, pp. 155–167.
7. Haland B., Braekke F.H. (1989) Distribution of root biomass in low-shrub pine bog. *Scand. J. For. Res*., 4, pp. 307–316.
8. Helmisaari H., Makkonen K., Kellomaki S., Valtonen E., Malkonen E. (2002) Below and above ground biomass, production and nitrogen use in Scot pine stands in eastern Finland. *Forest Ecology and Management*, 165, pp. 317–326.
9. Hoffman C.W., Usoltsev V.A. (2001) Modelling root biomass distribution in *Pinus sylvestris* forests of the Turgai Depression of Kazakhstan. *Forest Ecology and Management*, 149, pp. 103–114.
10. Jenik J. (1971) Root structure and underground biomass in equatorial forests. Proceedings of Brussels Symposium on Productivity of Forest Ecosystems, pp. 323–331.
11. Liepa I. (2005) Piesaistītā oglekļa un oglekļa dioksīda apjoma un dinamikas noteikšana Latvijas egļu mežos (Dynamics estimation of carbon and carbon dioxide accumulation in spruce forest in Latvia). Pārskats par Zemkopības ministrijas Meža attīstības fonda pasūtīto pētījumu. Jelgava, 3–19. lpp. (in Latvian).
12. Makkonen K., Helmisaari H.S. (1998) Seasonal and yearly variations of fine-root biomass and necromass in a Scots pine (*Pinus sylvestris* L.) stand. *Forest Ecology and Management*, 102, pp. 283–290.
13. Nadelhoffer K.J., Raich J.W. (1992) Fine root production estimates and below-ground carbon allocation in forest ecosystems. *Ecology*, 73, pp. 1139–1147.
14. Ohashi M., Kilpelainen J., Finer L., Risch A-C., Domisch T., Neuvonen S., Niemela P. (2007) The effect of red wood ant (Formica rufa group) mounds on root biomass, density, and nutrient concentrations in boreal managed forests. *Journal of Forest Research*. The Japanese Forest Society and Springer, pp. 113–119.
15. Polomski J., Kuhn N. (1998) *Wurzelsysteme* (Roots System). Haupt, Bern, 290 S. (in German).
16. Santantonio D., Hermann R.K., Overston W.S. (1997) Root biomass studies in forest ecosystems. *Pedobiologia*, 17, pp. 1–31.
17. Trettin C.C., Johnson D.W., Todd D.E. (1999) Forest nutrient and carbon pools at Walker Branch Watershed: Changes during a 21-year period. *Soil Science Society of America Journal*, 63, pp. 1436–1448.
18. Uri V., Lohmus K., Kiviste A., Aosaar J. (2008) The dynamics of biomass production in relation to foliar and root traits in a grey alder (*Alnus incana* (L.) Moench) plantation on abandoned agricultural land. *Forest Ecology and Management*, pp. 161–179.
19. Usoltsev V.A., Vanclay J.K. (1993) Biomass growth and structure of pine plantations and natural forests on dry steppe in Kazakhstan. Proceeding of IUFRO Conference on Growth and Yield Estimation from Successive Forest Inventories, Copenhagen, pp. 267–281.

EVALUATION OF RESULTS OF FOREST REGENERATION AFTER STUMP EXTRACTION IN FINLAND

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Abstract
The interest in stumps has increased with recent boost of the bioenergy in Europe. Fuel yield from stumps can be as high as from harvesting residues. The most valuable areas for stump extraction are spruce and pine stands on dry mineral soils. In Finland the utilization of stumps for energy is rapidly moving from the testing phase to forest practice. In 2005 the use of stump wood chips by heating and power plants totalled 0.4 mill. m^3, tripled the consumption of 2004, which corresponds to 14% of the total consumption of forest chips in Finland. Extensive whole-tree harvesting trials in Sweden demonstrate that removal of stumps and slash from clear-felled sites has a strong positive impact on natural forest regeneration. Results from Finland indicate that stump and slash removal can improve productivity and quality of subsequent re-planting of harvested forest sites. The majority of available studies on root rot control demonstrate that subsequent forest regeneration is more successful on sites where the stumps have been removed. The scope of this study was to evaluate quality of forest regeneration after stump extraction in Finland according to the national regulations in Latvia. Number, size, distribution and mortality of seedlings were estimated in 15 compartments. Additionally, moisture and compaction of soils were determined. Results of the study approved that regeneration of forest stands on fertile mineral soils after stump extraction was successful and combination of mounding with scarification during stump extraction provides sufficient growing conditions for new seedlings.
Key words: stump harvesting, forest regeneration.

Introduction

Extensive long-term whole-tree harvesting trials in Nordic countries clearly demonstrate that removal of stumps and slash from clear-felled sites has a strong positive impact on natural forest regeneration. After 7 years the number of naturally regenerated trees on sites with stump removal was by 10% higher, and on sites with combined stump and slash removal, by 51% higher than on control sites with stumps and slash left intact. In northern Sweden, after 11 years the number of naturally established trees on stump removal and whole tree removal sites was about twice as high as on control sites. In central Sweden, stump and slash removal resulted in up to 82% surplus of self-regenerated trees after 13...17 years. Stump and root removal is beneficial to vigour and survival of seedlings subsequently planted on clear-felled and stumped sites, and mainly due to soil disturbance (Vasaitis et al., 2008).

Results from Finland indicate that stump and slash removal could improve productivity and quality of subsequent re-planting of harvested forest sites. In agreement to whole-tree harvesting trials, the majority of available studies on root rot control also demonstrate that subsequent afforestation is more successful on sites where the stumps have been removed than on sites where the stumps were left intact. Seedlings mortality was attributed mainly to competition from herbs and shrubs. This repeatedly indicates that stumping significantly reduces the presence of ground vegetation competing with the replanted growing stock (Vasaitis et al., 2008).

Results from field experiments suggest no negative effect of stump harvesting on growth of the next tree crop. Furthermore, in the short term, stump harvesting is unlikely to reduce stand productivity but acknowledge that long-term empirical evidence is lacking. Such claims contrast with effects found in residue harvesting and the recommendations which encourage the return of wood ash to forests in order to maintain nutrient levels and sustain future productivity are provided. Where stump removal is undertaken in order to remove root rot, a comprehensive review undertaken discovered that in most cases, it leads to improved seedling establishment and gains in overall stand productivity (Walmsley and Godbold, 2009).

Stump wood extraction is completed in conjunction with forest regeneration operations, when site preparation work is integrated with stump harvesting. Recovery of logging residues and stumps also creates a favourable environment for forest regeneration by reducing the difficulty of the regeneration work and improving the quality and productivity of site preparation and planting work. As a result of stump removal, mechanized planting might be used as a cost efficient method of forest regeneration (Laitila et al., 2008).

The available data demonstrate that in most cases tree growth and stand productivity on stumped sites is either significantly higher or does not differ significantly from sites were stump removal was not conducted. In Swedish "whole-tree harvesting" trials, height increment of planted *Picea abies* and *Pinus sylvestris* after 7 years was, respectively, by 40...70% and by 15...20% higher on sites where stumps, slash and stumps were removed, as on control sites with conventional stem harvesting. After 22...27 years, the volume of self-regenerated trees (mainly *Betula sp.*

and *Picea abies*) on all tree removal sites was higher than that on sites with conventional harvesting. The positive impact of stumping was noted also for the stand volume, and the corresponding figures for stump removal and conventional harvesting sites (Vasaitis et al., 2008).

Mortality of seedlings after site regeneration is quite small, though there could be big variation within different growing sites or soil types. In stump extracted areas naturally regenerated coniferous seedlings amount is remarkable on fertile soils, this could lead to successful replacement of dead seedlings. However, in many cases naturally regenerated seedlings spread in uneven way and are mostly found next to mature forest stands (Melkas, 2006).

Unequipollent results are obtained in Latvia in studies implemented in 2008 (Lazdāns and Zimelis, 2008). Productivity of planting and early tending was considerably less in comparison to "business as usual" – planting in furrows. Mortality of seedlings was much higher, but generally due to damages done by tending; workers are not used to operate in uneven (not in rows) planting schemes and cut nearly half of seedlings. Similarly, significant decrease in planting productivity is explainable by the confusion, when workers constantly have to decide, which planting spot is better. This means that all operations in forest regeneration after stump extraction require more intelligence and professional skills, including knowledge in forestry. Workers in Finland, in contrast, are used to such an uneven planting scheme. Another difference from "business as usual" in Finland was type of soil preparation – no mounds, only scarification by ploughshare of the stump extraction head were used to prepare soil in trials in Latvia.

The aim of the study was to evaluate forest regeneration quality after stump extraction in Southern Finland according to the forestry quality requirements in Latvia, eliminating effects caused by non-trained workers at all production stages. Another target was to evaluate possibilities to use mounding with combined excavator head simultaneously with stump extraction as a soil preparation method in spruce stands on fertile soils.

Materials and Methods

Fifteen forest compartments in Southern part of Finland in Häme region located at longitude 61°03 N-61°20 N and latitude 024°46 E 025°43 E were selected for evaluation of results of forest regeneration. Stump extraction in the selected compartments was done in the autumn of 2008, except compartments No 6 and 7, which was harvested in 2004. The oldest stands were selected to see if the situation in regenerated stands changed in longer period. Forest regeneration with spruce was done in the spring of 2009, except compartments No 6 and 7, which was regenerated in 2005. Type of soil preparation – combined mounding and scarification with the excavator bucket was performed. At the moment the age of regenerated stands is 3...4 years. The area of the compartments is different – from 3.0 to 19.9 ha. Measurements were done in May, 2011. Weed control was applied only to some of the selected stands after planting, in spite of relatively fertile growth conditions, which is considerably different from the existing forest management practice in Latvia.

Characterization of the regeneration results were done by establishment of a set of round sample plots with an area of 25 m^2. Sample plots were located regularly after each 25...30 m according to the longest diagonal of the compartment. Height of living trees and the last year increment were measured to the living planted trees. Additionally, the cause of damages was determined for injured living trees and the number of dead planted trees as well as number of empty planting spots was estimated in each sample plot.

In Finland, National forest typology which is used, differs from the one in Latvia; therefore, for the study purposes forest type for each sample plot according to the national standards in Latvia was determined. Spruce is dominant tree species in all stands. The selected stands on dry mineral soils belong to *Hylocomiosa* and *Aegipodiosa* stand types, the stands on wet mineral soils belong to *Myrtilloso-sphagnosa* and *Myrtillosoi-polytrichosa* stand types.

Soil penetration resistance and moisture are important characteristics affecting growth of seedlings after regeneration; therefore, these values were determined in all sample plots on surface of the planting spots with living trees. Depth of the measurement was from 0 cm down to 80 cm or less, depending on depth of the bedrock layer. Simultaneously relative moisture of the topsoil layer (0...5 cm) was measured. Eijkelkamp digital penethrologger was used for both measurements. In total 5 measurements were done in each sample plot. Average values of the soil penetration resistance and average values for the topsoil layer (0...20 cm) were used in further evaluation.

The penethrologger accounts data of the power applied, which later are recalculated to the pressure units (MPa) using equation No. 1:

$$MPa = \frac{Power\ N}{2\ cm^2\ (cone\ area) \times 100} \quad (1)$$

Results and Discussion

Average increment in height of the planted seedlings in the selected compartments varies from 9.4 ± 0.5 cm to 26.6 ± 3.7 cm (Table 1), which corresponds to average values in Southern part of Finland (Saksa

Table 1

Summary of measurement results

Compartment No	Average height increment, cm	Initial number of planting spots per ha	Diseased seedlings, %	Average soil penetration resistance at 0...20 cm, MPa	Relative soil moisture, %
1	10.8 ± 2.5	2960 ± 160	1.4 ± 1.4	1.0 ± 0.1	14.1 ± 4.3
2	11.7 ± 2.1	2909 ± 320	-	1.0 ± 0.1	16.1 ± 3.9
3	13.1 ± 0.7	2722 ± 202	-	1.5 ± 0.1	14.9 ± 1.5
4	10.7 ± 0.9	3440 ± 181	2.0 ± 2.0	1.2 ± 0.1	13.3 ± 1.3
5	12.1 ± 1	3333 ± 169	2.8 ± 2.8	1.0 ± 0.1	10.7 ± 1.1
6	22.2 ± 2.1	4640 ± 601	2.2 ± 2.2	1.6 ± 0.1	9.5 ± 1.6
7	26.6 ± 3.7	3333 ± 581	-	1.5 ± 0.3	29.9 ± 8.8
8	12.3 ± 1.5	2067 ± 670	-	0.9 ± 0.1	20.1 ± 1.6
9	9.6 ± 1	2660 ± 277	-	1.1 ± 0.1	17.7 ± 0.5
10	11.8 ± 1.3	2259 ± 380	-	1.0 ± 0.1	13.6 ± 0.1
11	9.4 ± 0.9	3150 ± 324	-	1.0 ± 0.1	14.8 ± 0.1
12	10.2 ± 1.1	2892 ± 218	-	1.1 ± 0.1	15.7 ± 0.1
13	10.6 ± 0.9	3171 ± 401	-	1.3 ± 0.1	16.3 ± 0.1
14	9.4 ± 0.5	3415 ± 414	-	1.4 ± 0.1	6.1 ± 0.1
15	11 ± 0.6	2650 ± 356	-	1.3 ± 0.1	10.7 ± 0.1
Average	**11.6 ± 0.4**	**2910 ± 89**	**0.3 ± 0.2**	**1.2 ± 0.1**	**14.4 ± 0.5**

and Heiskanen, 2005). Diseased seedlings were not observed in the most of the sample plots, but average number of the diseased seedlings is 0.3 ± 0.2% from the initial number of planted seedlings.

The pressure resistance in topsoil layer (0...20 cm) is 1.2 MPa (Table 1). This value corresponds to weak compaction and according to other studies (Lazdiņa, 2008) such level of compaction is optimal for growth of roots. A value limiting growth of roots (3 MPa) is not exceeded in none of the objects. It means that soil compaction or too loose structure of soil is not negatively affecting the growth of seedlings in the selected stands.

Forest regeneration trials in Latvia approves, that mounding as a scarification method is improving growth conditions on loamy soils in *Hylocomiosa* stand type by increasing availability of nutrients in mounds. The seedlings on mounds have better growth characteristics, such as accumulation of biomass, than seedlings planted in furrows (traditional planting method) or in untreated soil (Lazdiņa, 2008). In contrast to that, in former farmlands plants grow better in furrows than on mounds, because the topsoil layer used for the formation of mounds is more compacted than the underlying soil layers, so the mound consists of 2 compacted layers, but furrow, if it is deep enough, is more similar to un-compacted forest soils. This is approved also by the soil pressure resistance measurement results, which are often above 3 MPa in mounds (Lazdiņa, 2008).

The average relative moisture in topsoil (0...5 cm) of the planting spots is similar in the forest regeneration sample plots established Latvia and Finland, 14.9 ± 0.4% and 14.4 ± 0.5% respectively, It was also found in earlier studies in Latvia that the relative moisture in topsoil layer on mound and in the furrow in early spring is not statistically different; 21 ± 0.5% and 20 ± 0.5% (Lazdiņa, 2008) respectively, no correlation was found in the study between the relative moisture and the pressure resistance of the topsoil layer (Figure 1).

Correlation between the relative moisture of the topsoil layer and the annual increment in height in 2010 in the selected compartments in Finland is not significant ($R^2 < 0.25$). Similarly, no relation was found between the share or appearance of the diseased trees and the topsoil moisture ($R^2 < 0.01$). Moderate linear correlation was found between the topsoil penetration resistance and annual increment ($R^2 < 0.38$); however, this result might have accidental character due to relatively small number of the selected compartments. Earlier studies in Southern part of Finland demonstrated that higher soil temperature and deeper layer of organic material in mounds positively affects increments in height of the spruce seedlings (Saksa and Heiskanen, 2005).

According to the study data, living seedlings occupy 86% of the initially prepared sampling spots, including 13.6% of planting spots occupied by living but damaged seedlings. Diseased trees occupy 0.3% of the planting spots, and empty planting spots are 13.9% of the total number (Figure 2).

According to the forest regeneration requirements in Finland, the average number of initially planted

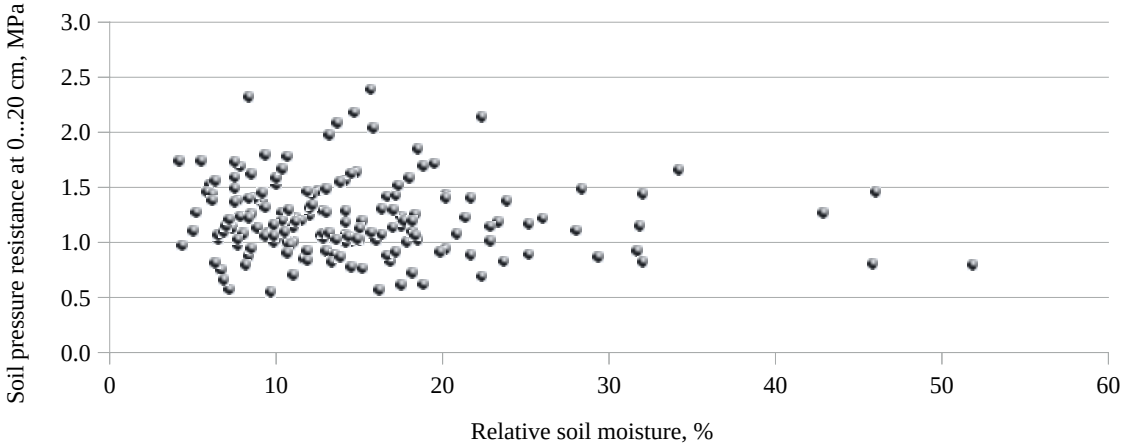

Figure 1. Relation between soil pressure resistance and relative soil moisture.

seedlings in the selected plots (2504 ± 81 per ha^{-1}) is by 30% more than it is set for spruce stands – 1800 per ha^{-1} (Kirjoittajia, 2007).

According to evaluation of the growth conditions in the selected stands and requirements for selection of species for the forest regeneration set in the Regulations of Cabinet of Ministers No 1453, paragraph 4.2 selection of spruce in all cases is the right choice. Similarly, spruce is right species for all sites according to the forest regeneration regulations in Finland (Kirjoittajia, 2007).

Distribution of the living seedlings (regularity) is even and corresponds to requirements set by the Regulations of the Cabinet of Ministers No 1453, paragraphs 4.3, 4.4.3, 4.5 and 5. Number of unused planting spots in all of the selected stands is sufficient to do supplementary planting if necessary as well as to select better planting spots during the regenerative planting.

According to requirements of the time limits for the forest regeneration in certain stand types set by Regulations of the Cabinet of ministers No 1453, paragraph 3.1, the regeneration in all of the selected stands is done in a timely fashion.

Average height of the measured seedlings in all sample plots is bigger than the threshold value (0.1 m) set by the Regulations of the Cabinet of ministers No 1453 for coniferous trees (Figure 3). This means that the selected stands can meet this requirement for the forest regeneration, too. The measured trees have good increment in height values (11.6 ± 0.4 cm), which also approves sufficient regeneration of the stands (Saksa and Heiskanen, 2005).

The only problematic requirement for regenerated stands according to the Regulations of Cabinet of Ministers No 1453 is density of stands. Most of stands reach the threshold value for spruce (2000 seedlings ha^{-1}); except compartments No 4, 10, 14 and 15 (Figure 4). None of them, except the compartment No 15, meet the national requirement for the forest regeneration in Finland. Forest owner can decide to plant more seedlings than necessary, which is the case in most of the selected stands. It is a common practice in Finland that forest owners are planting minimum

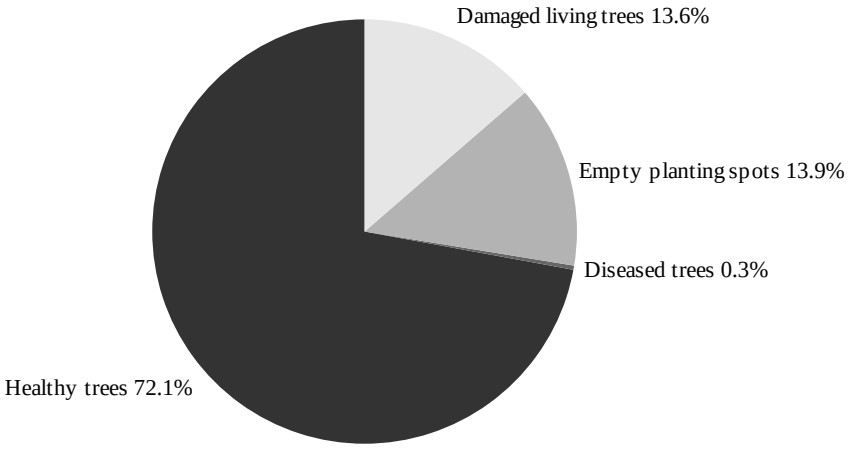

Figure 2. Relative distribution of initially established planting spots.

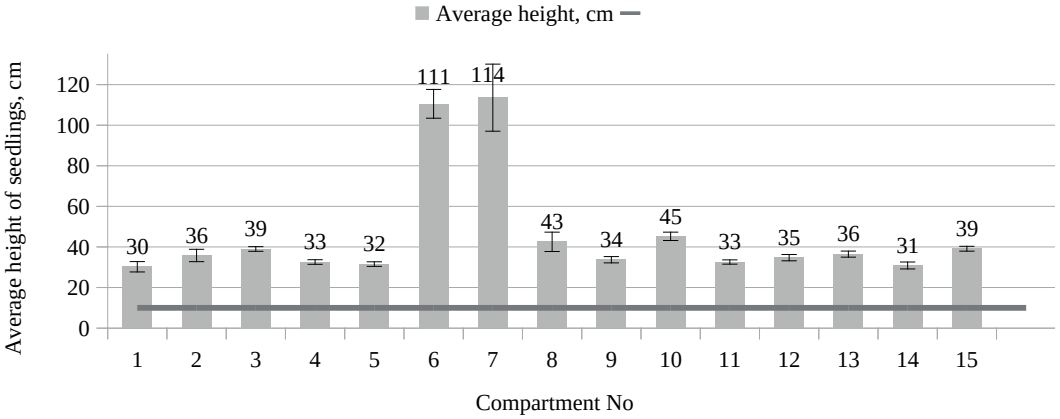

Figure 3. Average tree height in comparison to threshold value for regenerated stands according to national forest regulations in Latvia.

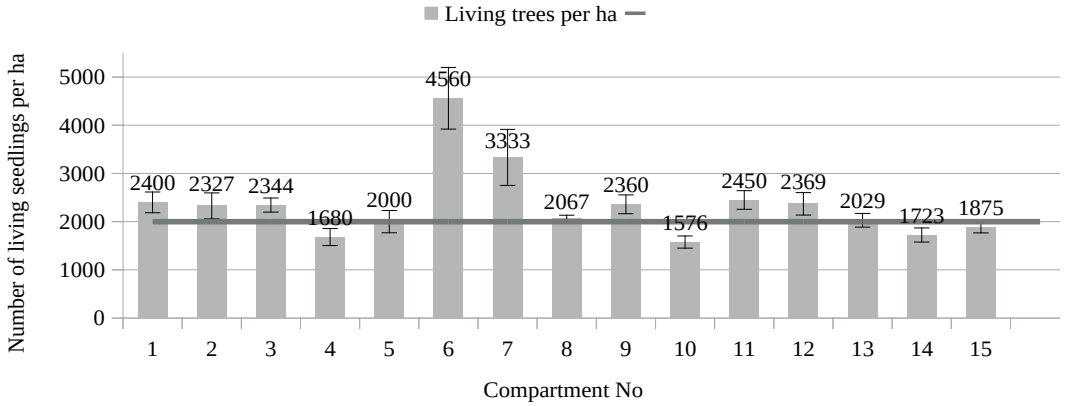

Figure 4. Number of living seedlings per ha in comparison to threshold values for regenerated stands according to national forest regulations in Latvia.

allowed number of seedlings and later complete the stand with supplementary planting. There is no difference in soil preparation type (Kirjoittajia, 2007). Share of diseased seedlings in the compartments No 4, 10, 14 and 15 is 0-2%, which means that the mortality is not a cause of insufficient number of seedlings. Measurement results show that specific characteristics of the compartments No 4, 10, 14 and 15 is considerably smaller efficiency of utilization of the available planting spots; average rate of utilization in other compartments is 90%, but in compartments No 4, 10, 14 and 15 it is 75% on average. Respectively, the reason for insufficient density of the regenerated stands is improper quality of forest planting.

In spite of excellent survival of seedlings, many of them (16% of survivors) have different damages caused by snow, wind, animals, diseases and other agents. Most of the damages in the measured plots were caused by animals – snapping off the tops of trees (74% of the total number of damages) by large artiodactyla and rodents (Figure 5). Studies in Southern Finland approved that in spite of the fact that the moose is considered to be the most harmful damage agent in young stands, spruce stands are the least interesting for this animal. Moose mostly damages spruce stands, when trees are 2...5 m high or when they are 10…20 years old (Jalkanen, 2001). According to this, in near future the evaluated stands will need monitoring of the damages and, if necessary, additional measures against the moose damages will be taken.

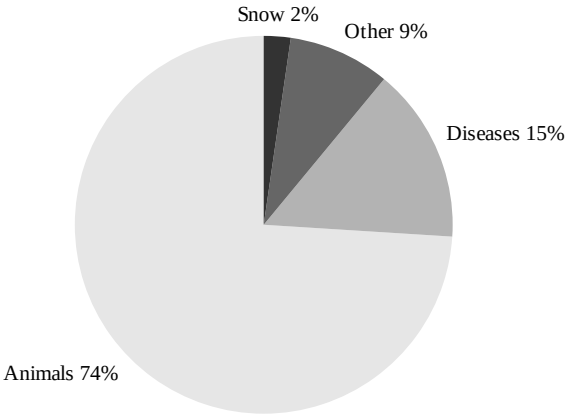

Figure 5. Distribution of damages according to their origin.

Root rot is another risk causing considerable damages in the spruce stands. Risk of infection is smaller in hilly areas and on elevated areas of the relief. These damages are more common on fertile sites and less common for peat soils. A deep peat layer usually reduces the risk of infection considerably. Selective felling, in contrast, increases the risk of damages. The risk of distribution of the root rot is higher in older stands, as function of age and diameter of trees count (Nuutinen, 2007). It was not possible to evaluate health status of the previous generation of trees, because the stumps were already harvested; however, it would be of high importance to consider this issue in further studies, because there are scientific evidences of positive effect of stump extraction on distribution of root rot and recovery of infected areas (Vasaitis et al., 2008; Zabowski et al., 2008; Petersson and Melin, 2010).

The most common causes of disease of seedlings are draught and insufficient compaction of soil around seedling causing formation of the so called "air pockets", prohibiting growth of roots into soil. Similarly, in Finland another important damage agent in planted areas is animals (Mangalis, 2004; Lazdiņa, 2008).

Conclusions

1. Results of the study approve that the regeneration of forest stands on fertile mineral soils after stump extraction was successful and combination of mounding with scarification during stump extraction provides sufficient growing conditions for new seedlings.
2. The rate of mortality is below 1% during 3-4 years, which is excellent value both, for Finland and Latvia. The reserves (number of living seedlings above the minimum threshold) is 30% on average. Additionally, about 14% sampling spots are empty. However, according to the literature the most significant damages will follow in later stages of development , so real success of regeration will be visible, when trees are taller than 5 m.
3. The regeneration quality fulfils the requirements of the national forest regulations in Latvia according to species selection, height of seedlings and regularity of planting; however, density of stand is insufficient in 4 stands. The reason is improper planting quality and not problems in soil preparation.
4. The working method is applicable in Latvia; however, the weed control might be serious problem in such stands in Latvia, because in many of the selected compartments in Finland there was no need for tending or weed control, in spite of the fact that trees were planted 3 years ago. The final response on quality of forest regeneration after stump extraction will give field trials in Latvia in similar growing conditions

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References

1. Jalkanen A. (2001) The Probability of Moose Damage at the Stand Level in Southern Finland. *Silva Fennica* 35, pp. 159–168.
2. Kirjoittajia U. (2007) *Hyvän Metsänhoidon Suositukset*. (Recommendations for good forest management). Metsakustannus Oy [2. painos, Lonnberg Print, Helsinki]: Metsatalouden kehittamiskeskus Tapio, pp. 59. (in Finnish).
3. Laitila J., Ranta T., Asikainen A. (2008) Productivity of Stump Harvesting for Fuel. *Forest Products Society. International Journal of Forest Engineering* 19, pp. 37–47.
4. Lazdāns V., Zimelis A. (2008) *Dažādu meža atjaunošanas paņēmienu pielietošanas iespēju analīze platībās, kur veikta celmu izstrāde enerģētiskās koksnes sagatavošanai, pētījuma pārskats*. (Evaluation of possibilities to use different forest regeneration methods after stump extraction for biofuel production, Research report). Latvijas Valsts Mežzinātnes Institūts "SILAVA", Salaspils, 68 lpp. (in Latvian).
5. Lazdiņa D. (2008) *Mehanizētās ietvarstādu stādīšanas tehnoloģiju mežsaimnieciskais novērtējums*. (Silvicultural Evaluation of Mecchinized Forest Planting Methods). Latvijas Valsts Mežzinātnes Institūts "SILAVA" Salaspils 99 lpp. (in Latvian).
6. Mangalis I. (2004) *Meža atjaunošana un ieaudzēšana*. (Forest Regeneration and Afforestation). [Rīga]: SIA "Et Cetera," 455 lpp. (in Latvian).
7. Melkas T. (2006) *Success of Planted Seedling Stands on Stump-harvested Soils*. Tampere University of Applied Sciences, Tampere pp. 44.
8. Nuutinen U., Tuula M. (2007) Assessing the Incidence of Butt Rot in Norway Spruce in Southern Finland. *Silva Fennica* 41, pp. 29–43.

9. Petersson H., Melin Y. (2010) Estimating the biomass and carbon pool of stump systems at a national scale. *Forest Ecology and Management* 260, pp. 466–471.
10. Saksa T., Heiskanen J. (2005) Multilevel Modelling of Height Growth in Young Norway Spruce Plantations in Southern Finland. *Silva Fennica* 39, pp. 143–153.
11. 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.
12. Walmsley J.D., Godbold D.L. (2010) *Stump Harvesting for Bioenergy – A Review of the Environmental Impacts*. Forestry 83 (1): 17-38, pp. 17–38.
13. Zabowski D., Chambreau D., Rotramel N., Thies W.G. (2008) Long-term effects of stump removal to control root rot on forest soil bulk density, soil carbon and nitrogen content. *Forest Ecology and Management* 255, pp. 720–727.

SYSTEM ANALYSIS OF PRODUCTIVITY AND COST OF STUMP EXTRACTION FOR BIOFUEL USING MCR 500 EXCAVATOR HEAD

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Abstract
In the 30ies of the 20th century stump extraction was identified as one of the most prospective technologies of forest sector to secure deliveries of solid biofuel. Now we are returning to the same challenges having the same targets – to secure energy independence and competitiveness of forest sector. MCR 500 is the prototype of combined stump extraction and mounding bucket for caterpillar excavator produced in Latvia by the LSFRI Silava and engineering company Orvi SIA. The device is made for extraction of stumps with diameter up to 50 cm. Additional benefit of the device is its ability to prepare soil for the forest regeneration by making mounds. The article summarizes results of productivity trials of stump extraction using the MCR 500 head and following forwarding of the material. Data from earlier studies are used to characterize comminution and road transport of stumps and chips. In total 3.5 ha were extracted during the studies. A harvested amount of stumps was estimated using biomass equations. It will be updated in further comminution studies. Average stock of extractable biomass (stumps and coarse roots) on the experimental sites was 28 tons ha^{-1}. Productivity of stump extraction was 2.4...3.4 tons per efficient hour. Consumption of efficient time for scarification of soil was 3.4...4.3 hours per ha. Forwarding took 30 min per load (2.6 tons per efficient working hour). Prime cost of chips according to biomass equations is 9.78 Ls LV m^{-3}, according to expert judgement based harvested stock is 6.38 Ls LV m^{-3}.
Key words: stump harvesting, forwarding, prime cost.

Introduction

Forest bioenergy is becoming increasingly important for the forest owners and forest industry in Latvia. Logging residues from clear-felling for biofuel production has already become widely accepted technology in state and private forests in Latvia. The demand for forest fuel is expected to grow due to increase of consumption in district heating sector and forest industries, like pellet production (Kons, 2011). Besides extraction of harvesting residues form clear-felling, a variety of other forest residues can be utilized for biofuel production. Extraction of stumps started in Finland and to some extent – in Sweden (Eriksson and Gustavsson, 2008). If cost efficiency is used to evaluate potential of potential resources, stumps are located in the next position after harvesting residues from clear-cuts, both, in terms of available resources and harvesting costs (Lazdiņš and Thor, 2009). However, stump biofuel has specific quality characteristics, making use of stumps complicated in conventional biomass boilers (Walmsley and Godbold, 2009).

Stumps consist of wood and bark of a tree below the stump cross-section. Recovery is performed with heavy machines after harvesting and removal of roundwood. Excavators equipped with a special stump extraction buckets that can pull and split stumps into smaller pieces are usually used for production. The harvestable dry mass of a stump-root system is 23...25% of the stem wood biomass, for both spruce and pine (Hakkila, 2004; Eriksson and Gustavsson, 2008). As a comparison, the crown mass and stem ratio is typically 40...60% for spruce and 20...30% for pine in Finnish and Swedish studies (Hakkila, 2004). Information about extractable biomass of stumps of deciduous trees is limited (Lazdiņš and Thor, 2009). The energy content of stumps varies in different references. About 140to160 MWh ha^{-1} can be harvested according to studies in Finland (Hakkila, 2004); in other publications 170 MWh ha^{-1} are mentioned (Nylinder, 1979); Tekes reported 200 MWh ha^{-1} (TEKES, 2004). Stump recovery can also reduce the cost of site preparation for replanting (Eriksson and Gustavsson, 2008).

Information about possibilities to merge extraction of stumps and scarification of soil is limited; however, there is scientific evidenceof improved natural regeneration, less insect damages and reduction of root rot distribution in the next generation stand (Saarinen, 2006). Therefore, the aim of the study is to evaluate productivity and prime cost of simultaneous stump extraction and soil preparation with the experimental stump extraction head MCR-500, forwarding and conventional soil preparation with a disc trencher as a control. The experiment will be continued with forest regeneration studies, which will provide information about the impact of stump extraction on the whole forest regeneration cycle.

Materials and Methods

The trials were established in 3 forest stands managed by Ltd. "Rīgas meži" nearby Ogre city (Table 1). Pine (P) dominant stand (176-18) was on naturally wet mineral soil. It was used generally to adapt to the working method. Two spruce (S) dominant stands were located on naturally dry mineral soil

Table 1

Characteristics of experimental stands

Code	Area, ha	Dominant tree specie	Stand type	Age decade	Stand composition	Harvested volume, m^3
176-18	2.7	Pine (*Pinus sylvestris* L.)	*Myrtilloso-sphagnosa*	11	7P3S	949
98-4	3.8	Spruce (*Picea abies* (L.) H. Karst.)	*Hylocomiosa*	9	6S2P2B + A, Ga	1542
104-9	1.5	Spruce (*Picea abies* (L.) H. Karst.)	*Myrtillosa mel.*	9	7S2P1B + A, Ga	293

Table 2

Work elements

No	Stump extraction	Disc trenching	Forwarding
1.	Tower turns	Preparations in the field	Driving in stand
2.	Driving in stand	Scarification	Manipulations with crane
3.	Reaching	Manoeuvring	Catching
4.	Catching	Other operations	Loading
5.	Pulling	Non-work operations	Unloading
6.	Splitting	Repairs	Sorting
7.	Shaking	-	Other operations
8.	Dropping	-	Non-work operations
9.	Scarifying	-	Weighing
10.	Other operation	-	Empty driving
11.	Non-work operations	-	Loaded driving

(98-4) and drained mineral soil (104-9). Other tree species represented in the experimental stands were silver birch (S), common aspen (A) and black alder (Ga). All stumps of Ga and other rare deciduous species were left in the stands.

All stumps were measured (species, height, diameter and visually identifiable rotting signs) and marked before extraction. The harvesting, forwarding and soil scarification trials were implemented from September to November, 2011. The time studies were implemented according to work elements are listed in Table 2. Forwarder loads was weighed using CAS scales RW-15P. Field computer with SDI software was used to record work elements. Time consumption is expressed in centiminutes (cmin.), which is 1/100 part of a minute.

Quality of soil scarification was estimated after stump forwarding using transect method – a set of 25 m^2 large sample plots located after each 25 m on the longest diagonal of the sample plot. Area and distance between mineralized spots were measured; minimal distance between suitable planting spots is at least 1.5 m.

The prime cost of production of stump chips was calculated using adapted version of the Flis cost calculation model (Thor et al., 2008). Productivity figures for stump extraction and forwarding were taken from the productivity studies. Maintenance costs and investments were considered as for new machines. Productivity figures and maintenance cost of stump truck, crusher, loader and chip truck were borrowed from earlier studies (Thor et al., 2008) using updated values for fuel cost and salaries.

Biomass was calculated using by recalculation of stump level diameter to diameter at breast height ($D_{1.3}$) and application of biomass expansion equations to estimate above- and below ground fractions of stumps (1st for spruce and pine and 2nd – for birch). For other species equation of dominant tree specie was applied. The same equations were used in previous studies (Thor et al., 2008).

$$D_{1.3} = a + b * D_0; where$$
$$D_{1.3} - diameter\ at\ breast\ height, cm;$$
$$D_0 - diameter\ of\ \ stump, cm;$$
$$a - coefficient, 0.7\ \ for\ spruce\ and\ -1.89\ \ for\ pine;$$
$$b - coefficient\ , 0.74\ \ for\ spruce\ and\ 0.87\ \ for\ pine. \quad (1)$$

$$D_{1.3} = -6.7 + 0.916 * D_0 + \frac{50.5}{D_0} \quad (2)$$

$$M_s = exp\left(-3.36 + 10.67 * \frac{D_{1.3}}{D_{1.3}+17}\right); where$$

M_s – dry biomass, kg. (3)

$$M_s = \exp\left(-3.97 + 11.05 * \frac{D_{1.3}}{D_{1.3}+15}\right) \quad (4)$$

$$M_s = exp\left(-3.68 + 11.54 * \left(\frac{2 + 1.25 * D_{1.3}}{2 + 1.25 * D_{1.3} + 26} + 0.02 + 0.05\right)\right) \quad (5)$$

$$M_s = \exp\left(-6.39 + 13.37 * \frac{D_{1.3}}{D_{1.3}+8}\right) \quad (6)$$

$$M_s = \exp\left(-6.34 + 13.29 * \frac{D_{1.3}}{D_{1.3}+9}\right) \quad (7)$$

Table 3

Characterization of extracted stumps according to biomass equations

Object	Number of extracted stumps per ha^{-1}	Extractable biomass of harvested stumps, kg ha^{-1}	Share of extracted stumps, %		Prepared mounds per ha^{-1}
			from number of stumps	from extractable biomass of stumps	
176-18	377	22907	90	72	315
98-4	324	27752	71	62	355
104-9	384	24970	63	53	1496

Stump biomass was calculated using exponential regression equations: spruce – 3rd equation, pine – 4th equation (Marklund, 1988), birch – the 5th equation (Repola et al., 2007). Equation for birch includes also large roots; for spruce and pine biomass of extractable roots was calculated separately usingthe 6th and 7th equation (Marklund, 1988), respectively. Above-ground part of stump is calculated separately using volume formula of cylinder and wood density factors from the guidelines for the greenhouse gas inventories (Penman, 2003). In this article.total biomass of stump and large roots (D > 5 cm) is called extractable biomass.

Results and Discussion

Average extracted biomass of stumps and roots according to the biomass calculations is 25.7 tons ha^{-1}. Average share of extracted stump biomass is 62% of total extractable biomass of the measured stumps. Average extractable biomass of stump is 73 kg (Table 3). If compared to harvested roundwood stock, share of extracted stump biomass is 7%. According to other study in Latvia, it is 12% (Thor et al., 2008). The same study also noted incongruity between the Swedish biomass equations and actually extracted biomass.

Average productivity of stump extraction is 2.7 tons per productive hour, but if soil scarification is not accounted – 3.4 tons per productive hour. Average time consumption for soil scarification is 3.4 hours ha^{-1}, when sufficient number of planting spots are prepared – 4.3 hours ha^{-1}. The most efficient stump extraction was in object No 104-9 (Table 4). In optimal working conditions an excavator can prepare 346 mounds per productive hour (10 sec per mound), if time consumption for stump extraction relevant work elements is not accounted (Table 5). According to the study results, it is possible to scarify 0.29 ha per productive hour. Notably that in the last stand (104-9) the productivity of soil scarification was 3 times

Table 4

Productivity of stump extraction

Object	Productivity of stump extraction, tons per hour		Productivity of mounding, mounds per hour	Productivity of soil preparation, ha per hour	
	total productive time	productive time for stump extraction		modelled scarification time[1]	to prepare 2000 mounds ha^{-1}
176-18	2.4	2.7	106	0.34	0.05
98-4	3.0	3.7	106	0.30	0.05
104-9	2.5	3.8	346	0.23	0.17

1 Excluding time consumption for stump extraction and treatment.

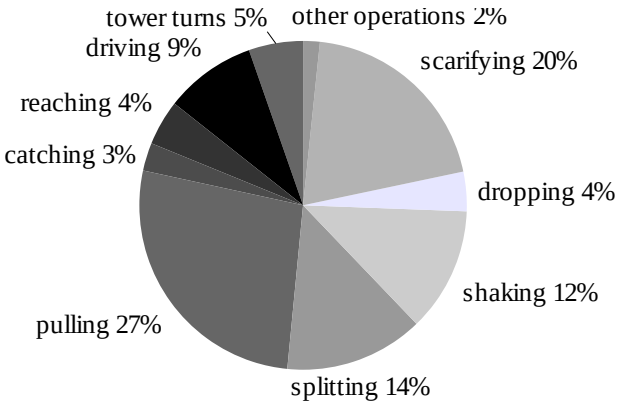

Figure 1. Share of work elements in productive time consumption.

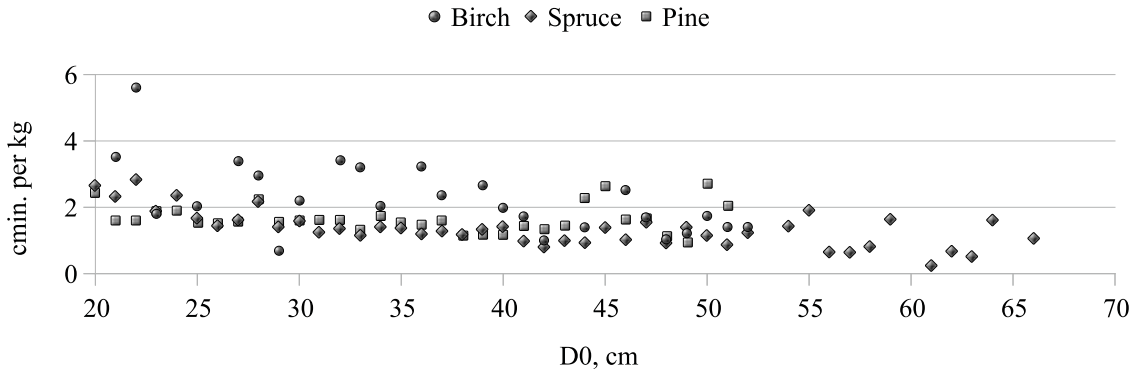

Figure 2. Productivity of stump extraction depending on dimensions of stumps.

higher than in the beginning. It is very probable that in real conditions the productivity will be similar to results obtained in the 104-9 or will be even better, if the pressure in the main cylinder of cutting knife is increased.

The most time consuming work elements are pulling, splitting and scarifying (61% of the total productive time, Figure 1). Technical improvements (increase of pressure in cylinder of the cutting knife) could increase productivity of pulling, splitting and shaking (cleaning of stumps). Productivity of scarifying can be increased by reduction of mounds per ha; however, much more studies are necessary to identify optimal number of the dedicated planting spots in different growing conditions.

Comparison of productivity of extraction of the stumps of different tree species and dimensions showsthat the MCR 500 can easily extract spruce stumps of any size and productivity constantly increases with the size of stumps (Figure 2). Productivity of extraction of birch stumps increases until D_0 reaches about 45 cm, then it becomes constant or decreases; however, productivity of large birch stumps is higher than of small stumps. Different results are obtained with pine stumps – there is no significant difference between productivity of smaller or larger stumps, but significant drop in productivity was observed, if D_0 of stumps is more than 45 cm. Productivity of the largest pine stumps is smaller than productivity of extraction of smaller pine stumps.

Comparison of work cycles, when 1 or several stumps are extracted approves hypothesis that simultaneous extraction is beneficial (Table 5), which means that in practice an operator should start pulling with the biggest stump, which will take also smaller surrounding stumps in a group of stumps, and not with smaller ones, which will be pulled out one by one.

Productivity of extraction of rotten stumps was significantly higher than average productivity figures. Time savings per stump, except time for soil scarification, was 17% on average. Most of reductions of the time consumption was in pulling and splitting operations (Figure 3). The damages by root rot may significantly reduce biomass of stumps, which is complicated to estimate using biomass equations; therefore, increase in productivity in practice might be lost in reduction of extracted biomass.

Average forwarder load was 7651 ± 272 kg. Average consumption of productive time in forwarding when calculated according to biomass equations was 22.8 ± 6.6 min ton^{-1} or 2.6 ± 0.8 tons per productive hour (Table 6). If time per load (20.3 min for loading and 10.1 min for unloading) is recalculated, results of the study are comparable with earlier stump

Table 5

Productivity of extraction of multiple stumps

Number of stumps per cycle	Share of total number of stumps	Share of total extractable biomass	Average extractable biomass of stump, kg	Average time consumption, seconds per stump
1 stump	85.9%	84.6%	69	62
2 stumps	12.4%	13.3%	76	60
3 stumps	0.9%	0.8%	62	58
≥ 4 stumps	0.8%	1.3%	41	27
More than 1	14.1%	15.4%	78	60

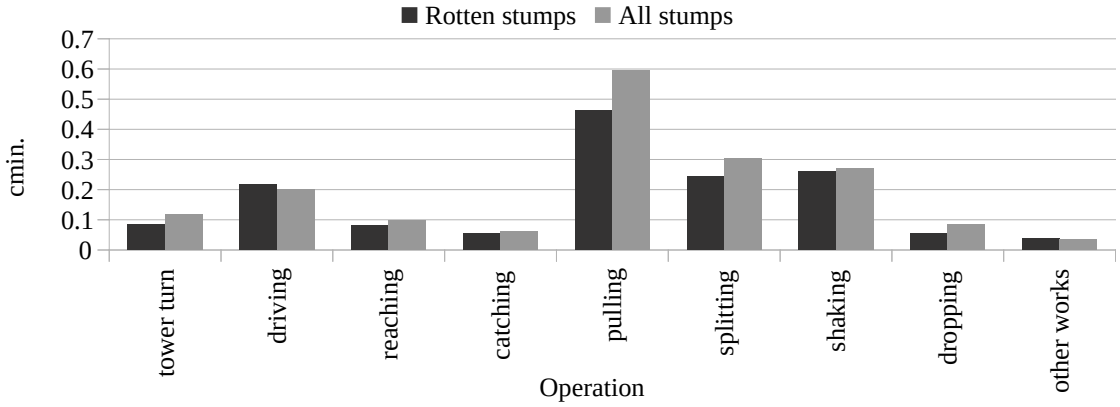

Figure 3. Productivity of extraction of rotten stumps – comparison of work elements.

forwarding studies (Thor et al., 2008); however, average load calculated by the biomass equations is 2 to 3 times smaller than in the same studies calculated according to weighed biomass. Average load according to biomass equations is 1.3 ± 0.4 tons, according to weighing data – 3.8 tons of dry mass.

The significant correlation was found between the load size and efficient time for loading ($R^2 = 0.78$). It can be expressed as a power regression (8th equation, Figure 4). It is also noticeable in Figure 5 that average load size depends on work conditions – it was considerably bigger in the object 98-4, where stock per ha was also greater than in other stands due to a larger dimensions of stumps.

$$E_0 = 1950.15 * M_s^{-1}; \text{ where}$$
$$E_0 - \text{productive time of loading, cmin.},$$
$$M_s - \text{biomass per load, kg} \quad (8)$$

Average productive time for scarifying of soil is 89 ± 18 min ha^{-1}. The soil preparation was more time consuming in *Myrtillosa mel.* stand type (106 min ha^{-1}).

Table 6

Productivity of forwarding

Value	Measurement unit	Numeric value
Average speed		
driving empty	km per hour	2.5 ± 0.2
driving loaded	km per hour	2.8 ± 0.2
Average load according to the biomass equations	tons	1.3 ± 0.4
Average unloading time	min load^{-1}	10.1 ± 0.6
Average loading time	min load^{-1}	20.3 ± 1.3
Average time per load, excluding driving	min load^{-1}	30.2 ± 1.3
Productivity		
total excluding driving	tons per hour	2.6 ± 0.8
total excluding driving and unloading	tons per hour	3.9 ± 2.3
unloading	tons per hour	7.9 ± 0.5

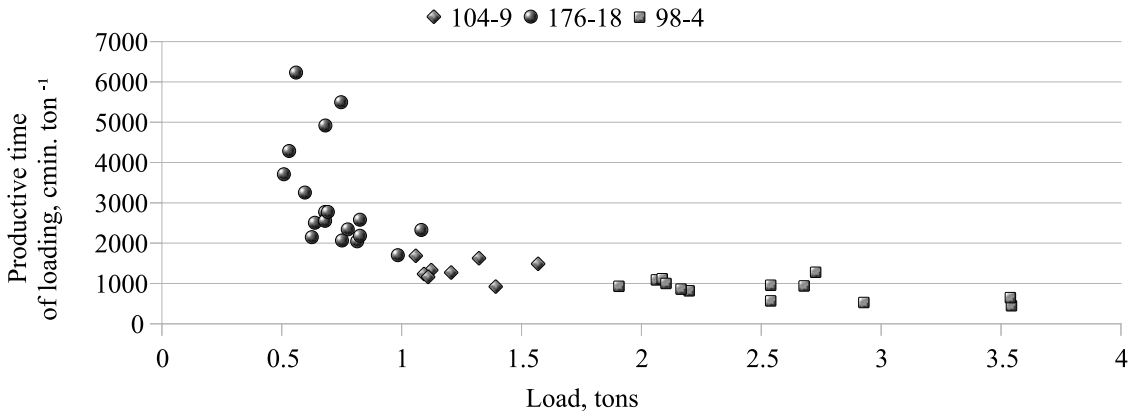

Figure 4. Productivity of loading depending on load size.

Table 7

Summary of prime cost calculation according to biomass equation figures

Position	Excavator	Forwarder	Stump truck	Crusher	Loader	Chip truck	Totals
Costs, thousands Ls year							
Investment	20.7	18.7	20.2	68.7	5.9	20.2	154.4
Staff	45.0	36.0	36.0	29.3	29.3	36.0	211.6
Operating	52.6	44.3	47.7	173.4	35.6	47.7	401.3
Total	118.4	99.0	103.9	271.4	70.7	103.9	767.3
Productivity (conversion factor ton to LV m^3 = 6), LV – loose volume							
LV m^3 per hour	12.50	7.54	18.84	60.00	250.00	25.93	-
LV m^3 yearly	217425	139640	64552	196632	768900	88875	-
Prime cost							
Ls LV m^3	2.35	3.07	1.65	1.42	0.10	1.20	9.78
Total cost, Ls ha^{-1}							1509
Proposed income, Ls ha^{-1} (price of chips assumed 7 Ls LV m^{-3})							1079
Compensation for soil scarification, Ls ha^{-1}							110
Net balance, Ls ha^{-1}							-319

Average productivity of disc trencher in the trials was 89 min ha^{-1}; cost of soil preparation with disc trencher 110 Ls ha^{-1}. Average number of planting spots in area prepared by the trencher was 1352 ± 50 per ha^{-1}, in area prepared by excavator – 1250 ± 72 per ha^{-1}.

According to the study results, prime cost of wood chips from stumps including stump extraction, forwarding, communition and road transport using the biomass equations derived values of harvested stock is 9.78 Ls LV m^3. Net balance according to average market price of wood chips is still negative (Table 7). If biomass is recalculated from forwarder loads obtained in other studies (Lazdinš et al., 2009), prime cost of chips would decrease to 6.38 Ls LV m^{-3}, if soil scarification is not included, thus, making stump extraction feasible.

Conclusions

1. The biomass equations used for calculations might underestimate biomass of stumps; therefore, the productivity figures and costs should be recalculated after comminution of stumps.
2. The experimental trials approved that simultaneous extraction of several stumps increases productivity. Extraction of rotten stumps also took less time – by 17% in comparison to average time consumption. However, it should be considered that biomass of rotten stumps might be smaller.
3. Average consumption of productive time for soil preparation, excluding loading and unloading of the device is 2.8 times less than during preparation of soil with excavator during stump extraction. This means that stump extraction, if directly compared to disc trenching is not feasible, but it might provide better growth conditions for seedlings, which can compensate additional cost.
4. Statistically significant difference between number of planting spots in extracted and control sites was found only in compartment No 176, where operator learned working method; therefore, the

result approves that stump extraction secures at least the same quality of soil preparation as disc trencher meeting national regulations on forest regeneration.

5. Productivity of forwarding per ton is twice less than estimated in other studies showing similar productivity results per load, which again points to necessity to use comminution derived data on produced biomass.
6. Prime cost of stump biofuel production, if biomass equations derived figures of productivity are used, is 9.78 Ls LV m^3; 55% of the cost relies to extraction and forwarding. Hourly cost of forwarder is significantly higher than service cost paid in trials, because old forwarder was used for the experiments and investment cost was not taken into account. The prime cost might significantly reduce after updating of the biomass figures; if expert judgement based values are used, production of chips would cost 6.38 Ls LV m^{-3}

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References

1. Eriksson L.N., Gustavsson L. (2008) Biofuels from stumps and small roundwood - Costs and CO_2 benefits. *Biomass and Bioenergy*. [Online] 32 (10), pp. 897–902.
2. Hakkila P. (2004) *Developing Technology for Large-Scale Production of Forest Chips. Wood Energy Technology Programme 1999–2003*. pp. 98.
3. Kons K. (2011) *Biomass Potential from Clear Fellings in Latvia*. Master thesis. Umeå, Sveriges lantbruksuniversitet, Institutionen för skoglig resurshushållning, pp. 44.
4. Lazdiņš A., Von Hofsten H. (2009) Technical and environmental issues of stump harvesting for biofuel production in Latvia. In: *Annual 15th International Scientific Conference Proceedings*. 2009 Jelgava, Latvia University of Agriculture. pp. 155–162.
5. Lazdinš A., Von Hofsten H., Lazdiņa D., Lazdāns V. (2009) Productivity and costs of stump harvesting for bioenergy production in Latvian conditions. In: *Proceedings*. 2009 Jelgava, Latvia University of Agriculture Faculty of Engineering. pp. 194–201.
6. 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*. 2009 Jelgava, Latvia University of Agriculture. pp. 147–154.
7. Marklund L.G. (1988) *Biomassafunktioner för tall, gran och björk i Sverige*. (Biomass equations for pine, spruce and birch in Sweden) Sveriges lantbruksuniversitet, Institutionen för skogstaxering. pp. 73.
8. Nylinder M. (1979) *Relationstal, träbränslen - olja* (Conversion factors, fuelwood – oil). In: Rapport - Sveriges lantbruksuniversitet, Institutionen för virkeslära ; nr. 110. Uppsala, [Sveriges lantbruksuniversitet, Institutionen för virkeslära]. pp. 45–47.
9. Penman J., Gytarsky M., Hiraishi T., Krug T., Kruger D., Pipatti R., Buendia L., Miwa K., Ngara T., Tanabe K., Wagner F. (2003) *Good Practice Guidance for Land Use, Land-Use Change and Forestry*. 2108 -11, Kamiyamaguchi, Hayama, Kanagawa, Japan, Institute for Global Environmental Strategies (IGES), pp. 587.
10. Repola J., Ojansuu R., Kukkola M. (2007) Biomass functions for Scots pine, Norway spruce and birch in Finland. *Working Papers of the Finnish Forest Research Institute*, 53, p. 28.
11. Saarinen V.M. (2006) The effects of slash and stump removal on productivity and quality of forest regeneration operations--preliminary results. *Biomass and Bioenergy*. 30 (4), pp. 349–356.
12. TEKES (2004) *Increased use of forest fuels to expand the raw material base. Stumps – an unutilised reserve*. pp. 2.
13. 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)*. Skogforsk, Uppsala. p. 75.
14. Walmsley J.D., Godbold D.L. (2009) *Stump Harvesting for Bioenergy – A Review of the Environmental Impacts*. Forestry (2010) 83 (1): pp. 17–38.

EVALUATION OF FOREST REGENARATION RESULTS AFTER STUMP EXTRACTION IN JOINT STOCK COMPANY 'LATVIAN STATE FORESTS'

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Abstract
With the increase in demand for renewable energy resources, new studies are carried out about under - utilized resources, namely, stumps. To begin to use stumps in industrial application, it is necessary to find out stump extraction influence on the environment, biodiversity, forest regeneration and other important factors. In Zemgale forestry, Misas and Klīves forest districts managed by Joint stock company "Latvian State Forests" (LSF) study on stump extraction in woodlands where clear-cuttings done in 2006 was carried out in the block No. 177, compartments No. 1 and 5, as well as the block No. 176, compartments No. 3 and 9. In these territories two research objects were made where in November-December 2007 stump extraction as well as soil preparation were performed. Main tasks of the project were to evaluate the results of forest natural seeding and coppice ingrowths in natural regeneration areas and evaluate the use of different methods for artificial reforestation with spruce and pine containerized seedlings. It was observed that more seedlings were cut off in the areas where soil scarification with stump extractor was performed if compared to areas prepared with a disc trencher.
Key words: forest regeneration, soil preparation, stump extraction.

Introduction

In Latvia, the use of tree biomass in energy production has two main advantages – resources are renewable and available locally. Forest area in Latvia counts for 3497.08 thousand hectares (+/- 23.53 thousand hectares or 0.67%) and covers 54.14% of Latvia's territory (Jansons, 2009). During the last ten years annual cutting volume of timber resources has been 10 to 12 million m^3 (State Forest Service, 2011). Unused annual potential of stump biomass in Latvia is around 1.3 million $tons_{dry\ mass}$ (Adamovičs et al., 2009).

Extraction of stumps improves soil structure by reducing its density and improving aeration processes, thus making favourable conditions for development of new stands. Removal of rotten spruce stumps from felling area reduces risk of new stand trees infection with root rot (Vasaitis et al., 2008).

In 2007, Joint stock company "Latvia State Forests" (LSF) in clear-cuttings of Zemgale forestry, Misas and Klīves forest districts performed stump extraction and soil preparation for afforestation with a specialized stump extractor bucket. Number of planting spots in extracted area and mineralised lines in control area were made in amount that corresponds to a necessary number of spruce or pine seedlings (Stādīšanas, sēšanas un …, 2011).

All forest stands in these sample plots were clear-cut with a harvester in the autumn 2006. Tree branches in all sample plots were compacted into strip roads, except in the block No. 177, parcel No. 5, where branches were left scattered in the felling area.

The extraction of stumps was done in November – December, 2007, a year after felling. Stump extraction in felled areas must be performed alongside with soil preparation for regeneration of areas where stumps have been removed by natural or artificial reforestation.

Aim: Verify whether it is possible to combine the stump extraction with soil preparation in Latvia weather conditions to prepare necessary number of planting spots to regenerate forest area with the spruce or pine containerized seedlings

Tasks:

1. Divide in rows and mark areas for the research;
2. Perform forest regeneration with the spruce of pine containerized seedlings;
3. Establish and monitor sample plots.

Materials and Methods

The total area of the study plots is 7 ha from which 5.7 ha were regenerated with spruce containerized seedlings and 1.3 ha with pine containerized seedlings.

There are *Hylocomiosa and Myrtillosa* forest growth types in the research areas located in the block No. 177, parcels No. 1 and No. 5; therefore, the parcel No. 1 was afforested with spruce containerized seedlings, but the parcel No. 5 with pine containerized seedlings.

After stump extraction, splitting and putting in piles along strip roads (stump piling along skid trail), with extraction-splitting device, it is possible to make soil scarification in mineralized ridges or small mounds. Stump extraction-splitting device in open position is pressed into soil and then by pulling upper tongue of device mineralized ridge in length of 1 to 2 meters or small mound by overturning turf is made. Stump extracting excavator while standing in one place can reach area from 24 to 28 m^2 (extraction-splitting device maximal reach range is 7 meters). Thus, it can prepare 6 to 8 mineralized ridges or small mounds. It

ensures necessary number of beds for planting spruce, pine or any other deciduous tree seedlings in felling area with removed stumps.

Research objects of the project - clear-cuttings with extracted stumps were placed in LSF Zemgale forestry, Misa forest district block No. 177, parcels No. 1 and 5, and for comparison clear-cuttings in Klīve forest district block No.176, parcels No. 3 and 9 were chosen.

In the block No. 177, parcel No. 1 four rows were established: the first row for 'natural regeneration', second row 'planting in rows', third row 'irregular planting' and fourth row 'ridges prepared with scarifier'. In the first row 'natural regeneration' stump extraction alongside soil preparation was done; the row was established at the side of the felling area provided for natural regeneration that borders with full-grown forest with superior stand of spruce ensuring afforestation of this area with natural seeding. In the second row 'planting in rows' stump extraction together with soil preparation was done; along the longest side of the felling area a line was stretched for an employee who will perform regeneration of the row to move along the line and plant spruce containerized seedlings. In the third row 'irregular planting' stump extraction as well as soil preparation was performed; in the row an employee would freely choose places where to plant spruce containerized seedlings. In the fourth row 'ridges prepared with scarifier' stump extraction simultaneously with soil preparation was performed where after that the soil was prepared with a scarifier 'Bracke T21.1'; employee would plant the spruce containerized seedlings in ridges prepared with a scarifier at the bottom of the ridge or on the top, depending on the conditions of the area. In the block No. 177, parcel No. 5 identical rows are established according to aforementioned method, where pine containerized seedlings are used in order to perform row afforestation.

In the block No. 176, parcel No. 9 soil was prepared with a scarifier prior to stump extraction. Reforestation was completed with spruce containerized seedlings planted in ridges prepared with a scarifier.

In the block No. 176, parcel No. 3 soil for afforestation was prepared with a scarifier in the spring 2007 and afforested with spruce containerized samplings planted in ridges prepared with a scarifier.

In all sample plots planting of spruce and pine containerized seedlings was done with a tree planting tool.

Planting material was delivered from the LSF nursery garden.

For further monitoring of seedling development, sample plots were established in spruce and pine afforested areas. In each plot on the longest diagonal four round shaped sample plots were established with the radius of 2.82 meters (25 m^2) (Noteikumi par koku ..., 2009). The number of trees was estimated with a similar method described in Cabinet Regulation No. 892 'Regulation on Tree Felling in Forest Lands'.

Data was processed using Microsoft Excel program Data Analysis, Descriptive Statistics.

Results and Discussion

Results of young forest stand preservation in sample plots (SP) are given in Table 1. Stand inventory results show that total loss of seedlings during the first vegetation period was not significant, especially taking into account a dry summer period from May to August in 2007 (Laika apstākļi gada …, 2007). However, during a young stand weeding process in irregularly planted areas around 600-700 seedlings per hectare was cut down. Here the large number of cut seedlings is related to dense vegetation and irregular planting method which requires additional concentration during weeding operation in order to find every seedling.

When making weeding in the areas where soil preparation was done with a disc trencher and a straight line planting of spruce containerized seedlings was done in ridges prepared with a disc trencher, the number of cut seedlings was 200 per hectare whereas in the areas where soil scarification was performed with a stump extraction-splitting device, the number of cut seedlings was 400 per hectare which could be explained with the fact that during the planting process it was not always possible to find prepared planting place for seedlings right next to the straight line. Therefore, planting here was done more in irregular manner. One can conclude that in irregularly regenerated forest areas where spruce containerized seedlings have not been planted in straight lines, the number of cut seedlings is two times larger and the weeding operation here should be done more carefully. Caution in weeding operation results in decrease of productivity and increase of costs.

After weeding in areas where soil preparation was done with a disc trencher and a straight line planting of pine containerized seedlings was done in the ridges, the number of cut down seedlings was 700 per hectare, but in the areas where soil scarification was performed with a stump extraction-splitting device and pine seedling planted irregularly, the number of cut down seedlings was 700 per hectare. In areas where the soil scarification was performed with a stump extraction-splitting device and the aim was to perform regular planting of pine containerized seedlings, it was not always possible to find a prepared planting place for seedlings right next to the straight line and planting there was done irregularly resulting in 400 cut

Table 1

Survival of seedlings in sample plots

Block and parcel No.	Code of enumerated sample plots	Number of seedlings in 25 m² sample plots						
		After planting		Dried and decayed seedlings		Cut down seedlings		Remaining number of seedlings, units per ha
		Number of seedlings, units per ha	Number of seedlings per SP	Number of seedlings, units per ha	Number of seedlings per SP	Number of seedlings, units per ha	Number of seedlings per SP	
Block No. 177, Parcel No. 1	St - E	2600	6.5 ±0.3	200	0.5 ±0.5	400	1 ±0.4	2000
	N - E	1800	4.5 ±0.5	200	0.5 ±0.5	500	1.3 ±0.5	1100
	F – E	2100	5.3 ±0.5	100	0.3 ±0.3	200	0.5 ±0.5	1800
Block No. 177, Parcel No. 5	St – P	3600	9 ±0.6	400	1 ±0.6	900	2.3 ±0.5	2300
	N – P	2600	6.5 ±0.3	-	-	700	1.8 ±1.0	1900
	F – P	3600	9 ±0.6	-	-	700	1.8 ±0.6	2900
Block No. 176, Parcel No. 9	A - F	2500	6.3 ±0.3	100	0.3 ±0.3	500	1.3 ±0.5	1900
Block No. 176, Parcel No. 3	N - F	2700	6.8 ±0.6	400	1 ±0.4	500	1.3 ±0.5	1800

Abbreviations:
St-E – Planting in rows;
N-E – Irregular planting;
F-E – Ridges prepared with a scarifier;
A-F - Ridges prepared with a scarifier, after that stump extraction was done;
N-F - Ridges prepared with a scarifier.

seedlings per hectare during the weeding operation. One can conclude that in irregularly regenerated forest areas where pine containerized seedlings have not been planted in straight lines, the number of cut down seedlings is 29% larger than in regularly planted areas.

It is possible to ensure favourable soil preparation for natural regeneration in sufficient quality as well as prepare necessary number of planting spots for planting forest when the stump extraction is done alongside soil preparation for the forest regeneration (Lazdiņš, 2011). In both areas - testing, and control, pioneer tree species like aspen and birch were more active in natural regeneration, but naturally regenerated pine and spruce seedlings were observed in very small quantities. Faster natural regeneration with aspen and birch matches with forest natural stabilization process, when after felling or destruction of a forest site, pioneer tree species are first to take over the area, forming unstable secondary forest sites (Bisenieks and Gavrilovs, 2006).

Conclusions

1. In Latvia, with the use of stump extraction-splitting device, it is possible to prepare necessary number of planting spots to regenerate forest area with the spruce or pine containerized seedlings.
2. The number of cut down seedlings was by 29% larger in areas where regeneration with a pine containerized seedlings done in straight lines than in areas where it done irregularly.
3. To reduce cut down seedlings during young stand weeding, it is necessary to work out teaching aids for the young stand weeding operation in areas where the soil preparation has been done with a stump extraction-splitting device.

Acknowledgements

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References

1. Adamovičs A., Dubrovskis V., Plūme I., Jansons Ā., Lazdiņa D., Lazdiņš A., Kārkliņš G. (2009) Biomasas izmantošanas ilgtspējības kritēriju pielietošana un pasākumu izstrāde (Application of criteria and development of activities for sustainable biomass utilization). Valsts SIA Vides projekti, 186, pp. 53–85. (in Latvian).
2. Bisenieks J., Gavrilovs U.G. (2006) Meža kopšanas ciršu modeļi mistrotām audzēm (Commercial thinning models in mixed forest stands). Available at: http://www.zm.gov.lv/doc_upl/Meza_kopsanas_cirsu_modeli_mistrotam,..._Silava.pdf, 22 February 2012 (in Latvian).
3. Jansons J. (2009) Par meža resursiem AS 'Latvijas valsts meži' apsaimniekotajos mežos pēc LVMI Silava veiktās meža inventarizācijas par meža resursu stāvokli valstī. Datu ticamības novērtējums (Forest resource's in areas of Joint stock company 'Latvian State Forests' performed forest management depending on the forest inventory done at LVMI Silava about the forest resource status in the state). Available at: http://www.google.lv/url?sa=t&rct=j&q=&esrc=s&source=web&cd=5&ved=0CD8QFjAE&url=http%3A%2F%2Fwww.efol.lv%2Ftools%2Fdownload.php%3Fname%3Dfiles%252Ftext%252FP%25C2RSKATS%2BLVM%2B2004_2009.pdf&ei=5DHYT53VD_LQ4QTXm9ifAw&usg=AFQjCNE8qf74j3UJE9KtSDn-WZv4O6X8Mw, 22 February 2012 (in Latvian).
4. Laika apstākļi gada laikā (Weather conditions during the year) (2007) Latvijas vides, ģeoloģijas un meteroloģijas centrs. Available at: http://www.meteo.lv/public/28787.html, 20 February 2012 (in Latvian).
5. Lazdiņš A. (2011) Meža atjaunošanas uz atcelmotām platībām rezultātu analīze Somijā (Analysis of forest regeneration results in stump extracted forest areas). Available at: www.silava.lv/userfiles/file/ERAF%20Lazdins/Lazdins%20ERAF%202011%2007%2029%20parskats.pdf, 22 February 2012 (in Latvian).
6. Meža apsaimniekošana (Forest management) (2011) State Forest Service. Available at: http://www.vmd.gov.lv/?sadala=82, 1 March 2012 (in Latvian).
7. Ministru Kabineta noteikumi Nr. 802 'Noteikumi par koku ciršanu meža zemēs' (Cabinet Regulation No. 892 'Regulations on Tree Felling in Forest Lands') (2009) Available at: http://www.likumi.lv/doc.php?id=147116, 29 February 2012 (in Latvian).
8. Stādīšanas, sēšanas un papildināšanas instrukcija (Guidelines for tree planting, sowing and supplementation) (2011) AS 'Latvijas valsts meži'. Available at: http://lvm.lv/lat/mezs/publikacijas/, 20 February 2012 (in Latvian).
9. 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(3), pp. 457–483.

MONITORING RESULTS OF ROUND WOOD UTILIZATION AND WOOD PROCESSING SUSTAINABILITY IN LATVIA

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Abstract
In society, discussions occasionally raise whether current level of wood cutting in Latvia is not too high to maintain sustainable forest industry and biodiversity. Cutting volumes for the state owned forests are calculated based on the model whose aim is to even the timber stock of each tree species in a long term period. The wood resource extraction in the private forests takes place according to free market conditions and depending on market prices. Therefore amount of round wood delivered from private forests can shift in a large range. The research had two main tasks. First task was to survey primary wood processing companies in Latvia and gather information about their round wood processing volumes, how their processing volumes divides between softwoods and hardwoods, dimensions of roundwood companies demand for production and assortment of produced materials. Second task was to evaluate round wood utilization balance in the territory of Latvia and estimate if current use of timber resources in Latvia corresponds to amounts that are sustainable. Research results showed that consumption of softwood timber in Latvia is close to maximum to perform sustainable forestry, but consumption of hardwoods is possible to increase at least by 20–25%. Survey of primary wood processing companies showed that round wood processing volumes in Latvia vary from 6 to 7 million m^3 annually and that large enterprises, which count only for 4% from total number of primary wood processing entities, process two thirds from annual round wood volume in country.
Key words: primary wood processing, timber resources, timber cutting volumes.

Introduction

In Latvia, timber resources have a significant economical, social and ecological value as forests cover 54% of territory and timber stocks are slightly increasing year by year. During last ten years, annual cutting volume of timber resources has been 10 to 12 million m^3 (State Forest Service, 2011). In society, discussions occasionally raise whether current level of cutting is not too high to maintain sustainable forest industry and biodiversity.

Forest industry consists of two important sectors – forestry and wood processing industry both working closely together. Together with connected sectors (transport, building, power industries, science, etc.), forest industry employs around 14% of employable population, from which most are employed in rural areas of Latvia. Total export value of goods produced by wood processing industry in 2011 reached 1.2 billion LVL. The base of wood processing industry is primary wood processing enterprises where round wood supplied from forests is converted to further processed products – sawn timber, veneer sheets, construction timber, timber particles in different size and other products, which are used in further downstream sector for creation of additional value. Central Statistical Bureau of Latvia gathers general data about the wood processing industry, but specific information about primary wood processing companies like geographical distribution, round wood processing volumes, division of processing volumes between softwoods and hardwoods, dimensions of roundwood companies' demand for production and assortment of produced materials is not being collected. This specific information is an important prerequisite for analysis of timber resource flow in Latvia and evaluation of round wood utilization sustainability.

According to Tunkele (2010), the economic activity in the state forest is carried out according to sustainable forest management principles. The wood resource extraction in the state forests is performed systematically and regularly with appropriate afforestation of felled areas. As a result, the wood resource availability planning and forecasting process is easier. The wood resource extraction in the private forests takes place according to free market conditions, where the final products are sold by the market prices when the price of supply matches the demand price. For example, during the period of 2007 – 2009, the wood resource extraction in the private forests decreased while wood supply from state forests was stable and even increased as a reaction to the low activity in private forests. But wood processing industry, which is a direct consumer of timber resources, is eager to find the answer about the kind and amount of round wood they can count on in a long term period (Robinson, 1987).

Every five years the State Forest Service calculates the cutting volumes for state-owned forests for the next five-year period. Five-year cutting volumes for state forests are calculated by using tree growth models (Ozolins, 2002) and models of forest operation management simulation (Dagis et al., 2006). The aim of these models is to even the timber stock of each tree species in a long-term period. Drawback of the method used by the State Forest Service is that it does not take into account the net present value of forests and does not try to increase this value for a long-term period. Thus, it is not guaranteed that the owner (state)

will get maximum long-term income. Anyway, if the state forest cutting volumes are determined by some kind of sustainable model, then sustainable timber cutting volumes of privately owned forests have not been analyzed very deeply.

Our research had two main tasks. First task was to survey primary wood processing companies in Latvia and gather information about their round wood processing volumes, how their processing volumes are divided between softwoods and hardwoods, dimensions of roundwood companies' demand for production and assortment of produced materials. Second task was to evaluate the round wood utilization balance in the territory of Latvia and estimate if current use of timber resources in Latvia corresponds to amounts that are sustainable.

Materials and Methods

The research work was carried out in the autumn 2011 within the frame of the project „Substantiation of deciduous trees cultivation and rational utilisation, new products and technologies" in Forest faculty of Latvia University of Agriculture. To reach the aim of the research, a questionnaire of primary woodworking companies was carried out. Information about enterprises was taken from the database of surveys made in years 2007 and 2009 when similar research by the Latvia University of Agriculture and the Latvian Forest Industry Federation was carried out. Additionally, contact information from public data bases available on the internet (www.1188.lv, www.zl.lv, www.viss.lv, www.lursoft.lv) was used. Survey was carried out over the phone call to every potential primary wood processing enterprise. In total, 453 enterprises were questioned and answers were received from 425 enterprises. From all respondents, 357 enterprises acknowledged themselves as primary wood processing enterprises on the market. Others were wood subsequent processing enterprises or recently had changed their activities to other industries. Data obtained during the questionnaire were analyzed in dynamics for years 2006 to 2010. For deeper analysis of primary wood processing companies, they were divided into groups according to their round wood processing volumes:

- large - above 50'001 m^3 annually;
- middle - 10'001-50'000 m^3 annually;
- small - 1'001-10'000 m^3 annually;
- micro - below 1'000 m^3 annually.

Additionally, companies were divided by tree species they process – softwood, hardwood or both.

For evaluation of the round wood utilization balance in the territory of Latvia, on the one hand, data form the questionnaire of primary woodworking companies were supplemented with data form analysis of external trade of forest industry (Latvian Ministry of Agriculture, 2010) and data of firewood usage in Latvia according to Central Statistical Bureau of Latvia. On the other hand sustainable timber cutting volumes in the territory of Latvia (Krumins et al., 2011) were taken. Both data sets were compared with each, other and conclusions of sustainable usage of timber were made.

Results and Discussion

Monitoring results of primary wood processing companies

During the time period of 2006 to 2008, because of global economic crisis and decrease in the demand for wood products, round wood processing volumes in Latvia decreased from 6.7 million m^3 in year 2006 to 5.7 million m^3 in 2008 (Figure 1).

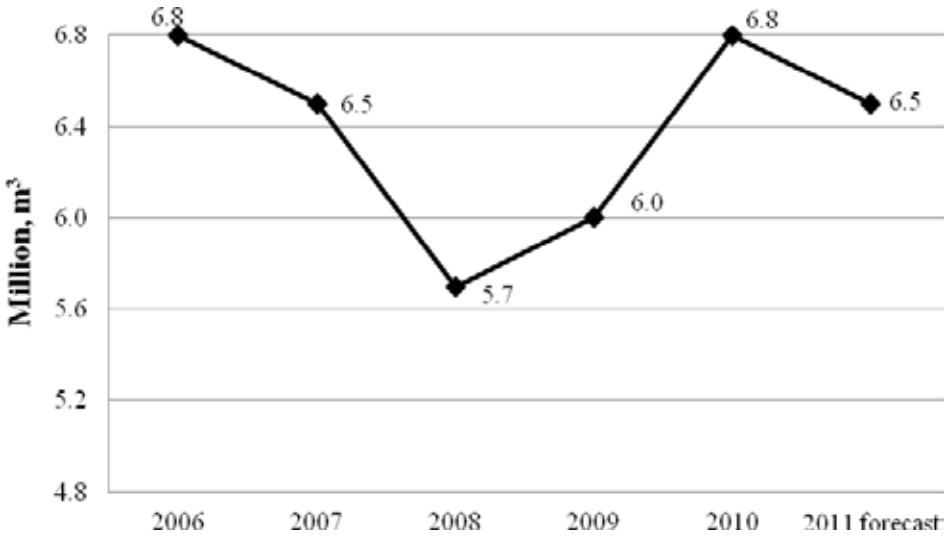

Figure 1. Total round wood processing volumes of surveyed enterprises during years 2006 to 2011, mill. m^3.

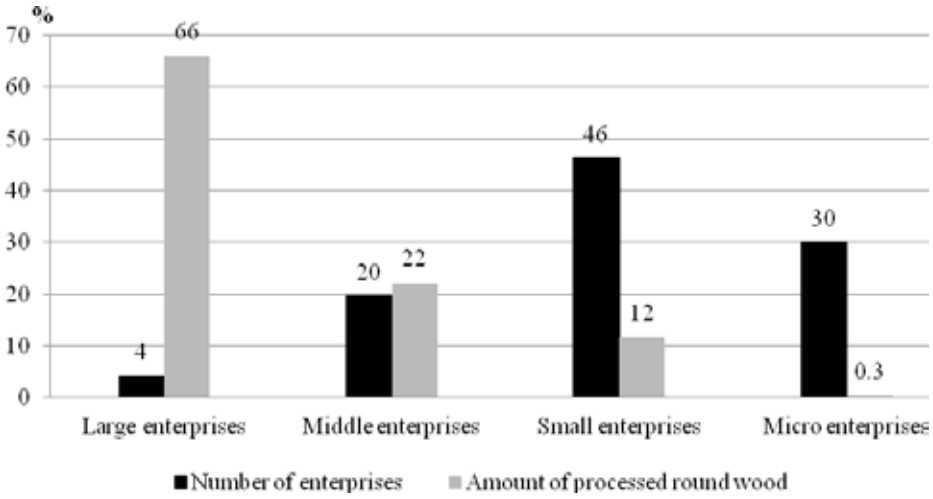

Figure 2. Proportional division of surveyed primary wood processing enterprises according to number of enterprises and amount of processed round wood in 2010, %.

After recovery of the demand for wood products in global markets in 2009 and 2010 and thanks to additional volumes of supplied round wood timber from state forest during periods of economic crisis, when private forest owners had significantly reduced their timber supply to wood processing industry, total round wood processing volumes in 2010 returned to the level they were before crisis and reached 6.8 million m^3. Experts of wood processing industry (members of Latvian Forest Industry Federation) forecasted that in 2011 round wood processing volumes will be a little lower than in 2010 – around 6.5 million m^3.

Large enterprises in 2010 counted only for 4% from the total number of primary wood processing enterprises, but processed two thirds from annual round wood volume in the country (Figure 2). Comparing with year 2008, large enterprises had increased their share in round wood processing volumes by 3%, which means that during past years they had become even more dominant on the timber market. Middle enterprises in 2010 counted for 20% from total number of enterprises, but processed 22% from annual round wood volume. In 2008, the share of middle enterprises in total number of enterprises was 15% and they consumed 20% from total round wood. Small enterprises in 2010 counted for 46% from total number of enterprises and processed only 12% from annual round wood volume. Compared with 2008, when these shares respectively were 56% and 16%, small enterprises had lost their market position in round wood processing. Almost one third (30%) from total number of enterprises were small primary wood processing companies, but they processed less than 1% from annual round wood volume in country.

After the questionnaire was finished, it turned out that compared with years 2007 and 2009, when previous questionnaires were held, in 2011 many wood primary processing companies had gone bankrupt or had switched their activities to other industries. Largest reduction in the number of enterprises was observed in the small and medium wood processing enterprise groups. Apparently for them it was more difficult to overcome global economic crisis than for flexible micro enterprises or stable large wood processing enterprises.

Processing volumes of primary wood processing companies in Latvia are mainly focused on the use of softwood timber. In 2010, softwoods made 75% from all processed round wood, and this proportion has been stable during last five years (Figure 3).

Deeper analysis of processed tree species according to the size of enterprises shows that 80% of large enterprises, 43% of middle enterprises and 47% of micro enterprises work only with softwoods (Figure 4). Small wood processing companies are most elastic in terms of tree species they process as 47% of them can work with both tree species - softwoods and hardwoods.

Survey results showed that in primary wood processing industry biggest demand is for middle and large dimension timber. Small dimension timber is demanded only in one third of wood processing enterprises specialized in softwood processing and in one tenth of enterprises specialized in hardwood processing. Therefore small - dimension round wood is not processed in sufficient amounts in local primary wood processing enterprises and is being exported. But - large dimension saw timber is welcomed in 85% of softwood and in 89% of hardwood primary wood processing companies.

Primary wood processing enterprises were asked to identify what is their production end-product – does their production process finish with wood pre-treatment products like sawn wood, packaging boards, log-house logs, veneer, plywood, plate materials,

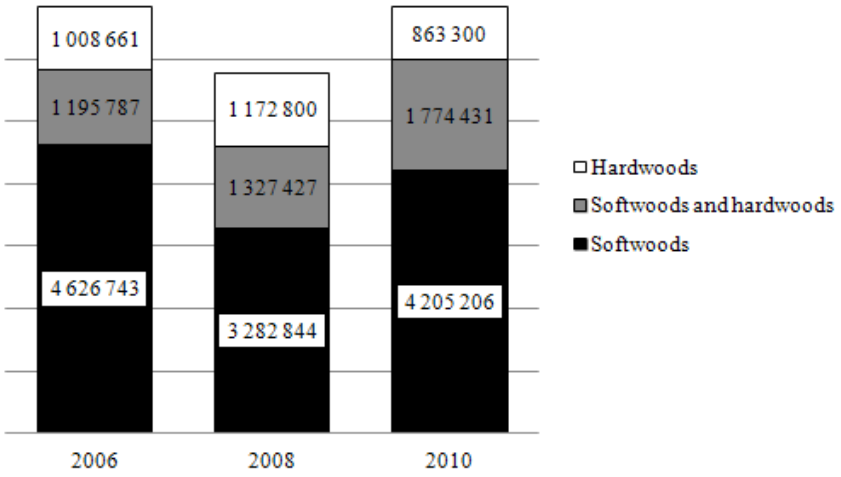

Figure 3. Division of round wood primary processing volumes by processed tree species in years 2006, 2008 and 2010, m^3.

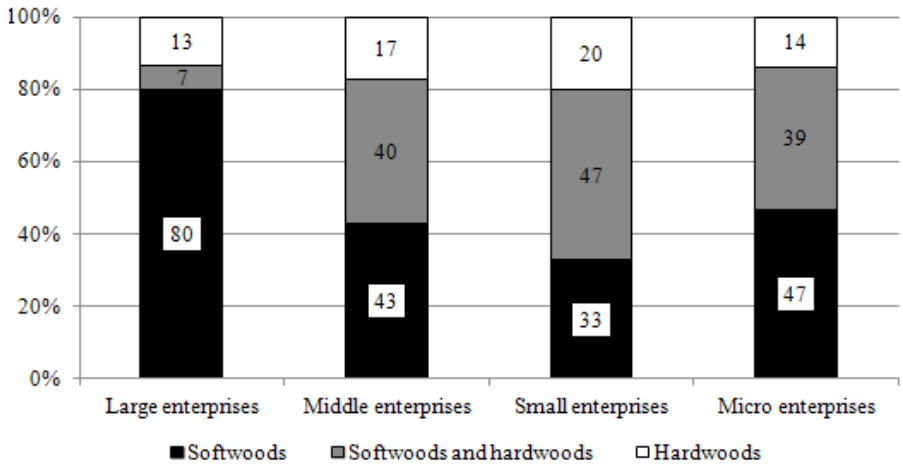

Figure 4. Division of processed tree species according to the size of enterprises in 2010, % from the number of enterprises.

firewood or do they manufacture also subsequent processing products like furniture, glued beams, wood pallets, doors and windows, carpentry and joinery production. Only 33% of large enterprises admitted that they do also subsequent production (Figure 5). Largest proportion of subsequent processing product producers were observed in the middle and small enterprise group where every second enterprise preformed deeper processing of timber, thus making larger added value to every round wood cubic meter processed. In the micro enterprise group, 41% of companies were producing subsequent timber products.

Analysis of usage of products produced by primary wood processing enterprises reveals that 61% of enterprises process round wood in products used afterwards in building and construction (Figure 6), 47% of enterprises produce source material for packaging, but only 28% of enterprises produce half-finished materials for furniture industry.

Deeper usage analysis of products produced by primary wood processing enterprises according to the size of enterprises showed that all large enterprises are producing products for building and construction, but 73% of large enterprises produce materials for furniture industry and packaging production. Middle and small enterprises mainly are focused on producing of building and construction materials (middle - 57%, small - 53%) as well as for production of packaging materials (middle 49%, small 52%). In smaller amounts are produced materials for furniture industry 17% of middle enterprises and 24% of small enterprises. Main focus of primary wood processing micro enterprises is on production of building and construction products. That is done by 76% of micro enterprises. One fifth (22%) of micro enterprises is producing packaging materials and 15% of micro enterprises are producing materials for furniture industry.

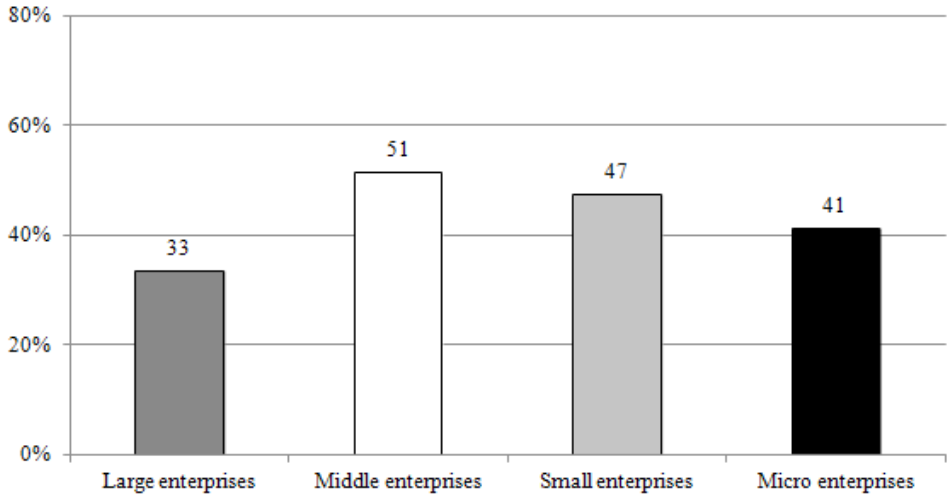

Figure 5. Share of primary processing enterprises performing also subsequent processing of timber, %.

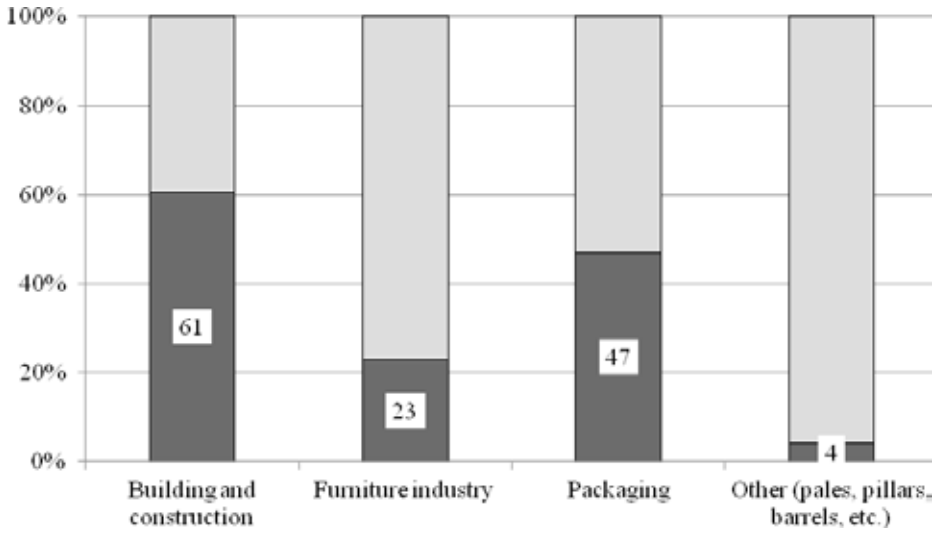

Figure 6. Usage of products produced by primary wood processing enterprises, %.

Round wood utilization balance in the territory of Latvia

Net export balance of round wood in Latvia in 2010 was 3.7 million m^3. Mostly small - dimension and low - quality round wood was exported. In external markets this timber is being used for pulp industry and bio energy production. However, around 0.7 million m^3 of unprocessed saw logs were sent to foreign wood processing companies.

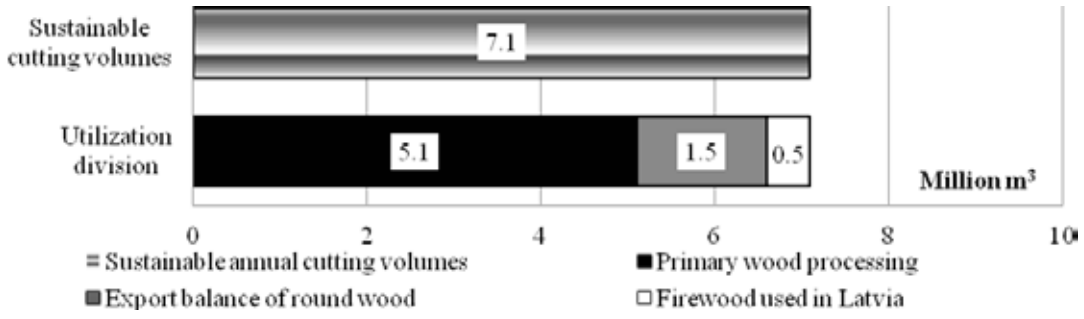

Figure 7. Softwood round wood utilization balance in Latvia in 2010, million m^3.

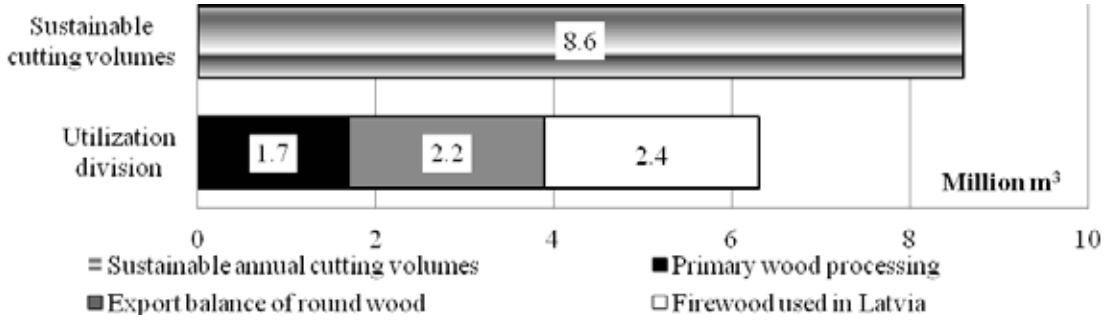

Figure 8. Hardwood round wood utilization balance in Latvia in 2010, million m^3.

Round wood utilization balance shows that softwoods (Figure 7) are being used more intensively than hardwoods (Figure 8). If hardwoods are used in amount of 73% from sustainable cutting volumes, then softwoods are used at maximum intensity. It means that consumption of softwood timber in Latvia should not be increased if we want to maintain sustainable forestry, but consumption of hardwoods is possible to increase at least by 20–25%.

However, to implement larger cutting volumes of hardwood than current ones, more detailed research should be done about availability of each single forest stand – how far it is from forest road, time of year the stand could be felled, interaction with proximal mature or young forest stands, intensity of surrounding clear cuttings, etc.

Hardwood consumption balance also shows that at the moment the wood processing industry, from calculated 8.6 million m^3 of round wood available for sustainable utilization every year, uses only 1.7 million m^3 of round wood, but at the same time 2.2 million m^3 of hardwoods annually are being exported.

Conclusions

1. In 2010 total round wood processing volumes in Latvia reached 6.8 million $m^{3,}$ which is the level they were before the global economic crisis. Experts of wood processing industry forecasted that in 2011 the round wood processing volumes will be a little lower than in 2010 – around 6.5 million m^3.
2. Processing volumes of primary wood processing companies in Latvia are mainly focused on use of softwood timber. In 2010, softwoods made 75% from all processed round wood, and this proportion has been stable during last five years.
3. Survey results showed that in primary wood processing industry the biggest demand is for middle- and large - dimension timber. Small - dimension timber is demanded only in one third of wood processing enterprises specialized in softwood processing and in one tenth of enterprises specialized in hardwood processing. Therefore small - dimension round wood is not processed in sufficient amounts in local primary wood processing enterprises and is being exported.
4. Little more than half of primary wood processing enterprises process round wood for products used in building and construction, 47% of enterprises produce source material for packaging industry, but only 28% of enterprises produce half-finished materials for furniture industry.
5. Round wood utilization balance shows that softwoods are being used more intensively than hardwoods. Hardwoods are used in amount of 73% from sustainable cutting volumes, but softwoods are used at maximum intensity. Consumption of softwood timber in Latvia should not be increased if we want to maintain sustainable forestry, but consumption of hardwoods is possible to increase at least by 20–25%.
6. Hardwood consumption balance shows that at the moment the wood processing industry, from calculated 8.6 million m^3 of round wood available for sustainable utilization every year, uses only 1.7 million m^3 of round wood, but at the same time 2.2 million m^3 of hardwoods annually are being exported.

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References

1. Krūmiņš J., Daģis S., Šmits I., Dubrovskis D. (2011) Sustainable supply of timber resources for wood processing industry in Latvia. *Proceedings of 5th International Scientific Conference "Rural Development in Global Changes"*, Aleksandras Stulginskis University, Kaunas, Lithuania, pp. 47–53.
2. Latvian Ministry of Agriculture (2010) Meža nozares produkcijas ārējā tirdzniecība (External trade of forest industry). Available at: http://www.zm.gov.lv/?sadala=289, 13 January 2011 (in Latvian).
3. Robinson G. (1987) *Resource Economics for Foresters*. John Wiley and Sons, US, 468 p.
4. State Forest Service (2011) Meža apsaimniekošana (Forest management). Available at: http://www.vmd.gov.lv/?sadala=2/, 22 February 2011 (in Latvian).
5. Tunkele S., Marcins J. (2010) The wood resource availability influencing factors in private forests in Latvia. In: *Annual 16th International Scientific Conference Proceedings "Research for Rural Development 2010" Volume No 1*, Latvia University of Agriculture, Jelgava, Latvia, pp. 188–193.

QUALITY CONTROL MANAGEMENT PROBLEMS OF WOODEN PRODUCT SURFACES

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Abstract
The added value of woodworks is determined by the surface quality because it is the first one seen and evaluated by the client. In the production process it is quite problematic to evaluate woodworks surface quality because of large production capacity, and the processed material can be instrumentally tested with a definite time shift. In production most frequently the surface quality is evaluated visually, which is not quite precise. At the same time during the mechanical processing of wood noise is caused by cutting tools as they gradually wear out. The same reasons influence the increase of noise and the quality of woodwork surface. The essence of the problem is to analyze the registered increase of the noise level at a definite workplace and simultaneously follow the surface quality of the processed material – roughness and wear-out of the cutting instrument. The objective of the paper is to research the method of the noise level data collecting and application in order to evaluate wooden product surface quality during wood processing by milling machines. It would provide an opportunity to update the management processes of massive woodworks, supervise the surface quality of woodworks, reduce costs and increase the added value.
Key words: woodwork, noise, surface quality, roughness.

Introduction

A demand for various woodworks constanly increases. Before consumers obtain them, mechanical processing and finishing of wood is performed. Mechanical processing of wood is sawing, drilling, planing, milling, etc. One of the quality indicators in the processing of massive wood is surface roughness before adhesion or finishing processes. Working with corresponding quality, additional processing operations are unneessary, since it makes the production process longer and more expensive. After processing massive wood by bed millers, quite often additional processing is not performed; semi-finished manufactures are glued or transferred to finishing. Wood surface is usually planed till a certain degree of roughness; thus, surface quality control is essential during processing to make the processed material comply with the required quality. While manufacturing, it is quite problematic to evaluate the compliance of surface quality to the required standard, and evaluation is mainly visual. The surface quality is influenced by various factors, for example, tree species, material supply speed, thickness of chips to be taken off, width of the surface to be processed, material humidity, technical condition of the bench, condition of the cutting tool, etc. All factors mentioned above mainly influence the dynamics of the cutting tool wear-out during processing, when the roughness of the processed surface gradually increases, but the surface quality decreases. During processing, the cutting tool wears out and the roughness of surface increases; thus, the level of noise grows which can be quite easily registered, saved and analyzed.

In woodworking noise is especially present in the mechanical processing of wood. Mainly the highest level of noise is at milling machines, which is related to a quite long contact line of the cutting tool with the processed surface. Large and heavy knife arbours are used in milling machines; they must be well-balanced and adjusted to avoid side noises and vibrations during processing the material. The noise level is a variable; thus, it shall be observed in the long run, at least in the inter-sharpening period of one cutting tool. Analyzing the increase of noise at a definite workplace, one can follow the surface quality of the processed material and the wear-out of the cutting tool. Determining the correlation between the increase of the noise level and the quality of the surface in various processing regimes in the inter-sharpening period of one cutting tool, the employer could effectively follow the wear-out of the cutting tool. It would provide an opportunity to control effectively the quality of woodworks surface. In addition to the surface quality control, an employer could follow the noise level at the workplaces as envisaged by Cabinet Regulations No. 66 'Labour Protection Requirements for Protection of Employees from the Risk Caused by the Noise of the Work Environment' ("LV", 21 (2786), 07.02.2003.). The regulations mentioned above determine that in Latvia an employer has to control the level of noise at the workplaces, it has to be done by verified devices, and create work environment that compy with the requirements of the regulations. Such control of the noise level would give an opportunity to an employer to control the condition of work environment in the processing workshop and improve it upon necessity. Besides the factors mentioned above, upon necessity an employer can control the load of a machine during the day and its technical condition according to the level of noise. If some of the rotating components of the machine are not respectively balanced, it will cause additional

vibration of the machine, thus increasing the level of noise at the workplace.

No research related to the wooden product surface quality measurement during wood processing by milling machines using the noise level data was found in scientific literature. The objective of the paper is to research the method of wooden product surfaces quality measurement and collect the noise level data in order to evaluate wooden product surfaces quality when milling machines are used.

Materials and Methods

Planed semi-finished manufactures or woodworks can be made having various surface quality. There is no single standard in the European Union defining woodworks surface quality and requirements. In production before adhesion and finishing works mainly visual evaluation is performed. Modern technologies in woodworking ensure good quality of surface without requiring any additional processing. If after mechanical processing of the surface grinding is needed, the price of the finished manufacture is higher. Depending on the final processing selected by the work performer, the client and the executor harmonize and discuss the required surface quality (Ozola et al., 2007). In order to evaluate wooden product surface quality, it is important to take into account all the factors affecting quality as well as the key characteristics of the product. In the mechanical processing of wood it is difficult to get absolutely smooth surface. The reason for such characteristics of the processed material is imprecise performance of cutting tools and machines, mistaken choice of a processing technology, and other cases that are not mentioned. Due to the impact of the factors mentioned above on the processed surface, the following types of irregularities can appear:

- shears and tears usually are placed in the longitudal direction of fibres and appeardue to bent fibres, curved fibres and branches;
- fluffiness is wood fibres badly split from the wood surface;
- stacks are deep tears in the surface of a semi-finished manufacture or a component left by the teeth of the saw. Stacks can have the shape of cavities, protuberances or channels, and the placement of this roughness on the surface depends on its origin;
- waviness or kinematical waves are surface elevations and deepenings in a definite sequence, which appears after wood processing by milling machines;
- roughness caused by flexible deformation in growth rings appears due to various hardness of early and late wood of annual rings, which influences the ability of wood to regain its prior shape after the pressure of a cutting tool on it;
- structural roughness is deepenings in the surfaces of components manufactured from chipboards and other analogous materials. These deepenings are formed due to various orientation of wood particles making material.

Surface roughness is described by the maximum height of irregularities Rz_{max}. In order to characterize surface roughness more precisely, a parameter Rz. – average height of surface irregularities being a base line border is used. All parameters are of equal significance; thus, one can reach the required processing quality or height of irregularities by any of them. In some cases the average step of irregularities by cavities (Grīnberga, 2002) serves as an additional parameter of surface roughness. Visually the parameters of surface roughness are seen in Figure 1.

In a majority of cases the height of maximum surface irregularities influences further processing of massive wood and the quality of final product. Upon mechanical processing wood gets surfaces of various roughness. After wood processing by bed-type millers the so called kinematical waves are left on the surface. The surface quality and suitability for further processing are actually determined by the height of waves. The surface smoothness for such surfaces can be determined by measuring parameters Rz_{max} from the highest points of surface protuberances to the lowest points of cavities. Digital indicators, for example, 'Millitast 1082' are used to determine the surface roughness or the largest cavity.

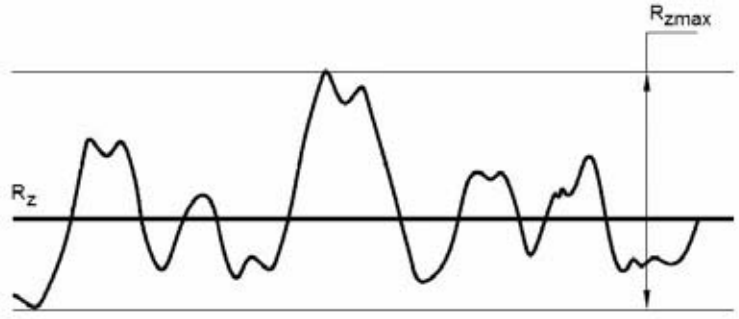

Figure 1. Parameters of surface roughness.
R_{zmax} – maximum height of irregularities; R_z – average height of surface irregularities.
Source: from the book of Grīnberga, 2002 with author's corrections

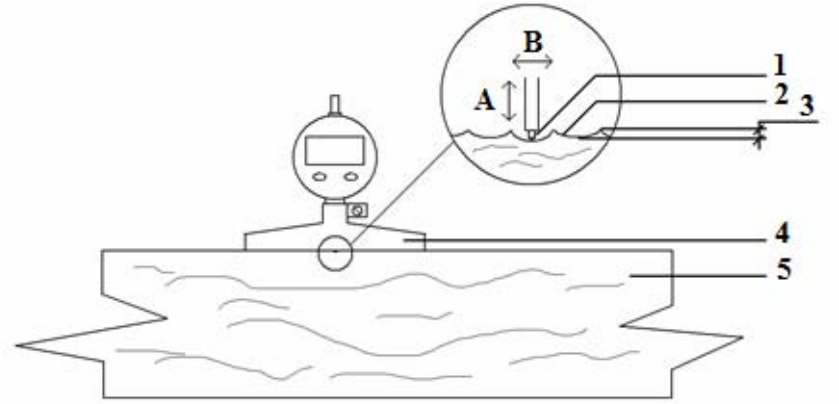

Figure 2. A digital indicator on the semi-finished manufacture to be tested:
1-measuring needle; 2-surface kinematical waves; 3-depth of surface irregularities;
4-measuring instrument 'Millitast 1082'; 5-semi-finished manufacture to be tested.

On the surface of the material to be tested, three places for taking measurements in the beginning, middle and end of wood are selected. One shall visually evaluate the places to be tested to avoid branches or any visible mechanical damages. Before measuring the zero mark must be set. It is done by placing a measuring instrument on glass and setting a zero mark. Afterwards, the digital indicator is placed on the surface to be tested, and the maximum depth of the kinematical wave in millimetres is determined by moving it slowly from the right to the left side. Taking of measurements is depicted in Figure 2.

The measuring instrument 'Millitast 1082', which is placed on the semi-finished manufacture, is seen from the side in Figure 2. The needle of the measuring instrument and surface kinematical waves are enlarged, which appear upon processing the surface by bed-type milling machines. In the figure under the letter 'A' there is shown how the measuring needle moves up and down as if it copies surface kinematical waves, at the moment when the measuring instrument is moved to the right and to the left- letter 'B' in the figure. Moving the measuring instrument slowly the depth of kinematical waves is determined, and the digital display shows the depth of irregularities with '-' mark; when the largest depth of irregularities is established, it is recorded. The average arithmetical value of at least three measurements is used to determine the surface roughness. As it is seen during processing, only a few sample semi-finished manufactures can be tested if respective room and tools are available. It is impossible to perform continuous surface quality control and management.

During wood mechanical processing by bed-type millers an increased level of noise appears, which gradually rises in the work process as the cutting tool, wears out and becomes less sharp. As the cutting tool wears out, the size of kinematical waves on the processed surface also increases, but surface quality decreases. To interpret the data collected by measuring the noise level, it is important to understand causes of noise as well as its characteristics. The noise created by a bed-type miller is divided into idle running noise; component-created noise; processing noise. The construction of equipment and technical condition can influence the level and nature of noise. The idle running noise includes two components:

- basic tone, which is wide tone hiss and is caused by fluctuations, separation of whirl from the rotating cutting tool and a field of flows around the cutting tool. It is also called aerodynamic hiss due to the origin of noise;
- rotation tone, which is caused by blades coming out of the cutting tool creating resistance of the air flow. It results in separate tones. These tones are caused by the increase of local pressure and time gap between noises. The rotation tone is the main reason for noise for a majority of woodworking machines and is the aim of various noise reduction measures.

Other type of noise is created by changing environment conditions, for example, the position of knives and their sharpness, speed, number of arbour turns, depth of the chips to be taken off, etc. (Heydt and Schwarz, 1977).

The sound intensity or loudness is measured in decibels (dB). Four factors determine whether the noise is dangerous: sound intensity or loudness, frequency or tone, periodicality – how often the sound is and duration – for how long period it sounds. The level of noise at the workplace cannot exceed the marginal value of noise exposition (87 dB(A)) determined by Cabinet Regulations No. 66 ("LV", 21 (2786), 07.02.2003.) or the level of noise at the workplace 140 dB(A). If the marginal value of noise exposition is exceeded, immediate labour protection measures shall be taken to reduce the noise level at least till the marginal exposition value (87 dB(A)).

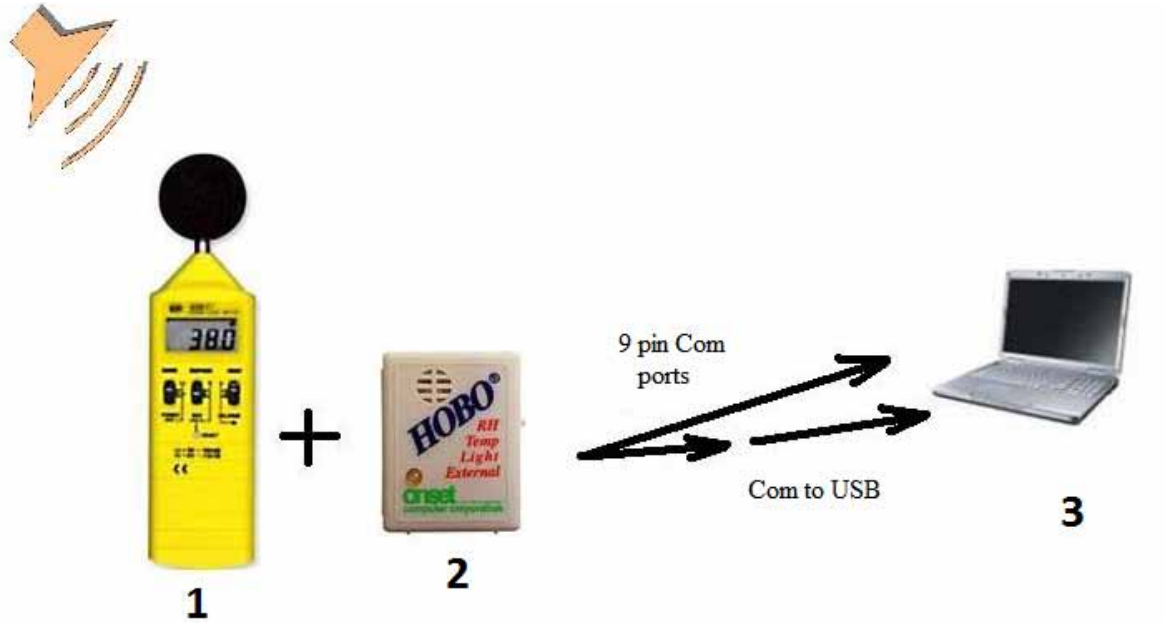

Figure 3. A set of devices for registering and keeping the noise level:
1– a device for registration of the noise level; 2– a module for reading and accumulating the noise pressure level; 3– a computer with software.

Noise and vibration are present in all woodworking and woodworks manufacturing processes. Practice shows that working with bed-type milling machines noise exceeds the maximum allowed level 87 dB(A) by 15...20 dB(A). Noise is also influenced by the vibration of a machine. Especially it is observed in cases when equipment is not sufficiently amortized, contains statically and dynamically unbalanced components, has insufficient amount of grease, and technical maintenance of equipment is not performed in time. Vibration can originate also in case the correct constructive solution of cutting tools is not selected or the way of cutting material is incorrect (Eglīte et al., 2004). In the wood cutting process the level of noise at the bed-type milling machines is increased; it gradually increases in the work process because the cutting tools become less sharp. Thus, the control and supervision of the workplace and noise level are needed to protect workers and avoid idle standing, which could appear if a worker becomes incapable. It would be ideally to follow simultaneously the dynamics of noise increase and surface quality during processing to judge about the compliance of surface quality to the required changing interval of the cutting tool under equal conditions of woodwork mechanical processing.

In order to measure noise, various measuring equipment can be used. Several measuring instruments, a computer and software are needed to register the noise level qualitatively. First, a device to register the noise level is needed. Often these devices are equipped with a display where one can follow the noise level during measuring. The devices are battery-operated or accumulator-operated and are small and portable. Using such devices, it is easy to measure noise at the workplace, but if data processing is needed, a module for reading and accumulating the noise pressure level 'HOBO' is needed in addition. It is a small device connected to the noise registration device. Its main task is to register changes of the noise level. It is needed to accumulate data and later on analyze them with a computer. The changes in the noise level are recorded by an interval of 0.5 seconds, which is very fast and gives a lot of data to be analyzed. Noone could write data by hand so fast. In order to install and start the module for reading and accumulating the noise pressure level, a computer with software is needed in a set with the device. The components are depicted in Figure 3.

First, the module is connected to the registration device, afterwards – to the computer by a special cord. When the module is connected to the computer and all necessary settings are completed, it is started by the help of special software. Measurements are taken at least in the distance of one metre from the surfaces and walls reflecting sound. The measuring tool is placed on a stand 1.5 – 1.7 m above the ground level. The microphone is turned into the direction of the largest source of noise. After taking measurements, the module and the device for data registration are repeatedly connected to the computer to save the obtained data. It has be noted that the measuring devices must be verified and calibrated.

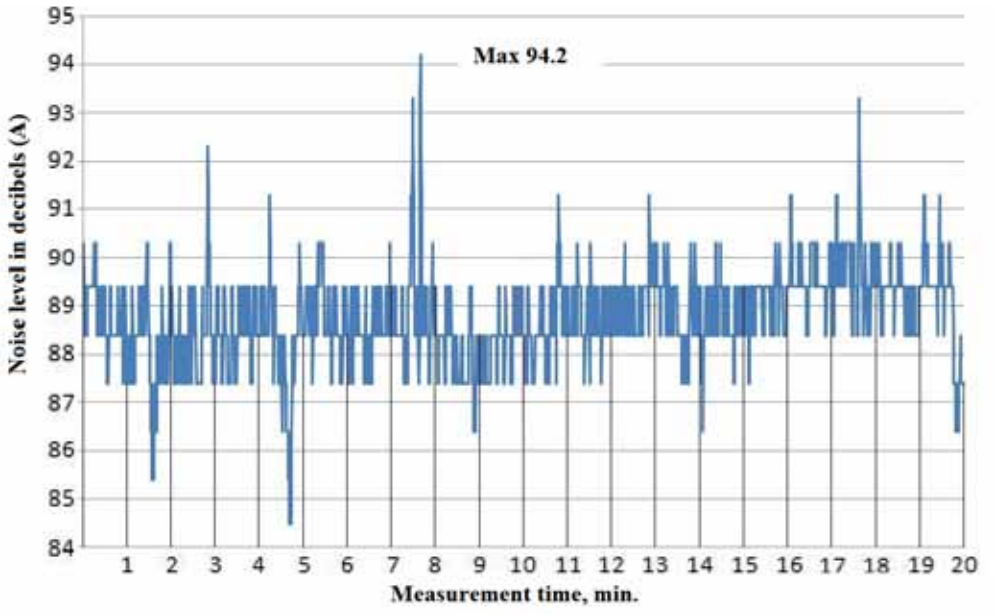

Figure 4. Noise level at the bed milling machine during processing.

Results and Discussion

The measured data can be accumulated at the workplace and obtained in a digital form letting to save, send and analyze them with various software. The example measurement of the noise level was taken using the mentioned devices in order to represent the noise level data collected during wood processing by milling machines. They are shown in Figure 4.

In the specific sample the noise level at the bed-type milling machine during wood processing is seen; the measurements are taken within the interval of twenty minutes. As it is seen, at this workplace mainly the noise level reaches 87.5 dB(A) to 90 dB(A). The peak noise 94.2 dB(A) observed for a short moment is not typical for the whole processing period. In order to control and manage surface quality applying registration of the noise level, it is essential to measure the noise in the cutting tool inter-sharpening period. Thus, the noise level should be measured as soon as the cutting tool is changed till the moment surface quality is not satisfactory anymore. The noise level can be measured continuously or cyclically. Analyzing the obtained data, it is noticeable that during processing the noise slightly increases due to the wear-out of the cutting tool deteriorating surface quality. Thus, it is possible to forecast surface quality under certain processing conditions depending on the noise level. When the processing conditions change, for example, tree species, thickness of the chips to be taken off, or the speed of material supply, the noise level will change as well, but the correlation with the noise level during processing will remain the same. Taking into account the fact that no research related to the connection between the noise level and the wooden product surface quality was found in literature, this work could be used as a sourse for further analysis of the advantages and possible problems of the present method at the planed wooden products manufacturing. The introduction of the method requires investment, specific knowledge, strict and definite work procedure and culture, which in the future could simplify the management of the production process and make it easier.

Conclusions

1. The analysis of the wooden product surface and noise level characteristics as well as the affecting factors allows to interprete the collected data and their application in order to evaluate the surface quality when milling machines are in use.
2. During wood mechanical processing it is impossible to control instrumentally the surface quality of planed woodworks, which is influenced by the size of the processed material, high speed of machine supply, high – microscopic precision of measurements.
3. Improving (digitalizing) the methodology for registration of noise level measurements, it would be possible to follow not only the surface quality of the processed material and identify the degree of wear-out for the cutting tool, but also develop the duration of the cycle for changing cutting tools, register the executed work and load of machines, as well as execute technical maintenance regulations and repair.
4. The noise level and the quality of processed material have common reasons of origin related to the wear-out of cutting tools, technical conditions of machines and solution of other important issues related to manufacturing.

References

1. Eglīte I., Cīrule L., Mustapa L., Vilmane A. (2004) *Ergonomika darbā* (*Ergonomics at Work*), Lietuva: Spindulys, 176 lpp. (in Latvian).
2. Grīnberga M. (2002) *Kokapstrādes tehnoloģija* (*Woodworking Technology*), Rīga: Jumava, 293 lpp. (in Latvian).
3. Heydt F., Schwarz H.J. (1977) Gerauschuntersuchungen und Massnahmen zur Gerauschminderung an mehrseitigen Hobel und Frasmaschinen fur die Holzbearbeitung (Noise Research and Noise Abatement on Multi Side Woodworking Planers and Moulders). In: *Holz als Roh- und Werkstoff*, SpringerLink. S. 323–326. (in German).
4. Ozola L., Skrupskis V., Pavītols A. (2007) *Koks būvniecībā* (Wood in Construction). Rīga: Stilus, 256 lpp. (in Latvian).
5. MK noteikumi Nr.66 (2003) Darba aizsardzības prasības nodarbināto aizsardzībai pret darba vides trokšņa radīto risku (Labour Protection Requirements for Protection of Employees from the Risk Caused by the Noise of the Work Environment) Available at: http://www.likumi.lv/doc.php?mode=DOC&id=71039, 17 February 2012 (in Latvian).

IMPACT OF PROVENANCE ON WOOD AND FIBRES PROPERTIES OF LODGEPOLE PINE, GROWN IN LATVIA

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Abstract
Lodgepole pine (*Pinus contorta*) samples from three different provenances in Canada were investigated. All trees were the same age and had been grown in Latvia in similar conditions. Lodgepole pine of Summit Lake provenance had higher wood density (503 kg m^{-3}) and a higher late wood content (46%) in comparison to Fort Nelson and Pink Mountain provenances. Investigation of chemical composition of wood indicated Summit Lake provenance wood as superior in cellulose content (49.7%), but no differences in lignin and extractives content were found between samples. Kraft pulp yield of Summit Lake samples (48%) was the highest, but the handsheet strength properties were relatively higher for pulp from Pink Mountain provenance pine wood.
Key words: Lodgepole pine, provenance, fibre, paper strength.

Introduction

Lodgepole pine, *Pinus contorta* Douglas ex Louden var. *latifolia* Engelm. Ex S.Watson, is a valuable and widespread species found throughout western North America, where it is planted as a part of sustainable forestry practice. Historically, trees that were well adapted to the soil and climatic conditions succeeded and thrived, whereas those ill-adapted failed. Over many generations, the successful species have adapted to local conditions resulting in the genetic make-up of wood land that is of local provenance. Today we say that the provenance of a tree describes the seed it grew from and where the seed was collected. Trees grown from imported seed may differ significantly in important characteristics.

A review by Elfving et al. (2001) describes the introduction of lodgepole pine in Sweden. The large-scale introduction of this tree species in Sweden started in the 1970s. The planted area has reached about 600,000 ha, corresponding to nearly 3% of the forested land.

Nevertheless, we did found only few published papers on the impact of provenance on the composition and properties of the lodgepole pine wood and fibres. McLane et al. (2011) investigated climate impacts on lodgepole pine radial growth in a provenance experiment. Sixteen sites in British Columbia, Canada, and Yukon and 12 populations were chosen to represent a broad spectrum of temperature and precipitation levels and geographic locations. The authors found modest differences in sensivity to climate among the populations from climatically divergent provenances growing in the same climatic region that they attributed to local adaption.

At the Latvian State Forestry Institute "Silava" the trials for transferred Scots pine and lodgepole pine provenances are performed (Jansons and Baumanis, 2008; Jansons et al., 2009).

As to the Scots pine (Jansons and Baumanis, 2008), in three experimental places in Latvia provenances from several countries were tested. The introduced pines at 28-years age had significantly thicker branches (German provenances – 9%, Polish – 6%) and crooked stems (German provenances – 35%, Polish – 12%) compared to the local material. Latvian pine provenances exhibited good growth and stem quality characteristics and also survival was higher than that of foreign provenances. The research suggested that use of foreign Scots pine plant material in Latvia is not advisable. The results by Jansons et al. (2009) revealed up to two-fold difference in total above-ground biomass among *Pinus contorta* families indicating the importance of the selection of the appropriate plant material for establishment of biomass plantation. The authors found that biomass production capacity of *Pinus contorta* on average is 3.5 t_{dry} per ha yearly. The number is almost 2.5 times higher than for *Pinus sylvestris* but notably lower as compared to hybrid aspen or Salix clones.

The objective of the present study was to investigate the wood and fibres properties of *Pinus contorta* three provenances, thus supplementing the data obtained earlier (Sable et al., 2012).

Materials and Methods

Samples were collected during 2009 and 2010 on an experimental site in the central part of Latvia (latitude 56°41', longitude 24°27'). Plant production for the experiments started in 1983; planting was carried out in 1985 on dry, sandy soil (*Myrtillosa* forest type). Initial spacing was 1 x 2 m; no thinning had been carried out prior to the collection of sample trees.

Lodgepole pine *(Pinus contorta)* was represented by 26 sample trees, grown from the seeds from 3 provenances from Canada, British Columbia: Pink

Mountain (latitude 57°00', longitude 122°15'-45'), Fort Nelson (latitude 58°38', longitude122°41'), and Summit Lake (latitude 54°24', longitude 122°37').

Wood samples were chosen based on randomized number methods. Approximately 2 cm thick wood discs were made and treated by No. 150 sandpaper to determine the latewood content at the height of 1.3 m. The discs were dried at room temperature and scanned by "Canon 4400" using calibrated "Leica ImagePro6" software.

All tree samples were debarked and wood density samples were made from the stem part at the height of 0.5 to 1.0 m; all wood chemical analyses and kraft cooking were made from the stem wood at the height of 1.0 to 1.3 m.

All samples were ground in a Wiley mill to pass through a 0.6 mm screen. The ground wood particles were then Soxhlet extracted with acetone for 8 h to quantify the extractable components gravimetrically after rotary vacuum-evaporation, and expressed as a percentage of the original weight of the wood sample. The extracted lignocellulosic material was then air-dried and analyzed for cellulose and lignin contents as follows. For Kürschner cellulose content determination according to TAPPI 203cm-99 (TAPPI, 2000), 2 g of the sample of extracted wood was used. It was transferred to a 250 mL reaction vessel, and 150 mL of nitric acid and ethanol solution was added. Wood samples were heated in a water bath at 92 °C for about 20 min; then the solution was exchanged for a new one. The procedure was repeated 7 times, and finally the fibres were washed with warm deionised water. The dry substance was weighed to determine Kürschner cellulose gravimetrically.

Lignin content was determined by the acetyl – bromide method using UV spectroscopy according to Iiyama and Wallis (1988; 1990), and Hatfield et al. (1999). The method is based on the small weight of the wood screened sawdust sample treated with 25% of acetyl bromide in a glacial acetic acid solution. Perchloric acid was used as a catalyst for the acetylation reaction. Absorption was measured at 280 nm and absorption coefficient was adopted to be equal to 20.0 L $(g\ cm)^{-1}$. The content of lignin in wood was calculated by the equation (1),

$$w(\%) = \frac{A \cdot V \cdot 100\%}{a \cdot b \cdot m \cdot 1000} \quad (1)$$

where A is the absorption at 280 nm; V is the volume of the mixture, mL; m is the weight of the sample, g; a is absorption coefficient, 20.0 L $(g\ cm)^{-1}$; and b is the thickness of the cuvette, cm.

Pulp was obtained by kraft pulping procedure. About 200 g of wood chips was cooked in a 2 L laboratory digester at 170 °C. The white liquor contained 57.4 g L^{-1} active alkali as NaOH, sulfidity was 29.8%, and liquor to wood ratio was 4.5 L kg^{-1}. Before cooking, the digester was left overnight at room temperature to impregnate wood chips with chemicals. Then the autoclave was placed into the heating unit and the temperature was increased from room temperature to 170 °C in 104 min, and cooked for 75 min. After the cooking procedure, the autoclave was immediately placed in water - ice bath to terminate the delignification reactions. The kraft pulp fibres obtained were carefully washed with warm water until the filtrate was colourless and the washing waters became neutral. The delignified fibres were treated in a standard PTA disintegrator for 30000 revolutions, then filtered and collected on a Büchner funnel, and dried at room temperature to determine the total kraft pulp yield.

Klason lignin content was determined according to the TAPPI Standard T 222 om-98.

The kraft pulp fibre samples were dried overnight at 50 °C, and the moisture content was measured to determine fiber weight for dimensions and coarseness measurements. Accurately weighed samples were then re-suspended in 20 mL of de-ionized distilled water, and fibre properties (length, width, form, coarseness and fines) were determined on a Lorentzen & Wettre "FiberTester".

Standard handsheets were made according to ISO 5269/2 on a PTA "Rapid-Köthen" handsheets paper machine. Handsheets were prepared at the grammage 75 g m^{-2} to determine tensile and burst strength indices (ISO 1924-1 and ISO 2758, respectively).

Data collected were analysed with appropriate statistical software (SPSS). ANOVA procedure was used for determination of factor (provenance) effect on the inspected properties. If the provenance effect was significant ($p<0.05$), Bonferroni test was used *post hoc* to determine which provenances differed.

Results and Discussion

Obtained measurements on the tree stem diameter at 1.3 m height varied widely, from 7.9 to 17.9 cm (Fig.1). There were slight, but not statistically significant differences between lodgepole pine trees from Pink Mountain (13.1 ± 2.6 cm), Fort Nelson (11.2 ± 2.3 cm) and Summit Lake (13.0 ± 2.3 cm) provenances.

Wood density values for the different provenance pine samples were well separated, with significance $p<0.05$. As shown in Figure 2, Summit Lake

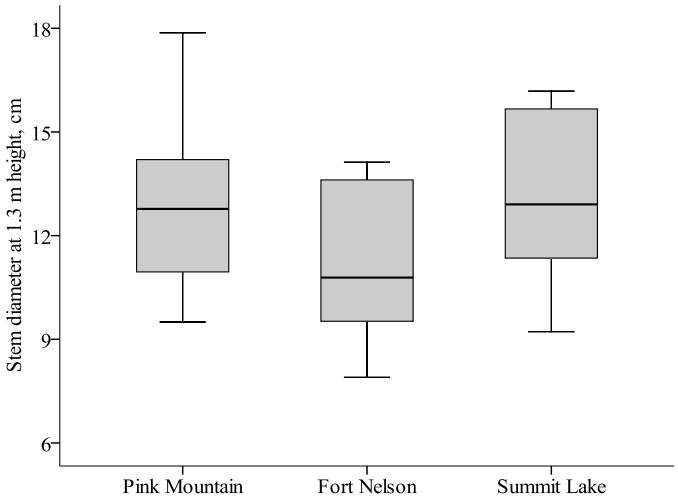

Figure 1. Stem diameter values of lodgepole pine from different provenances.

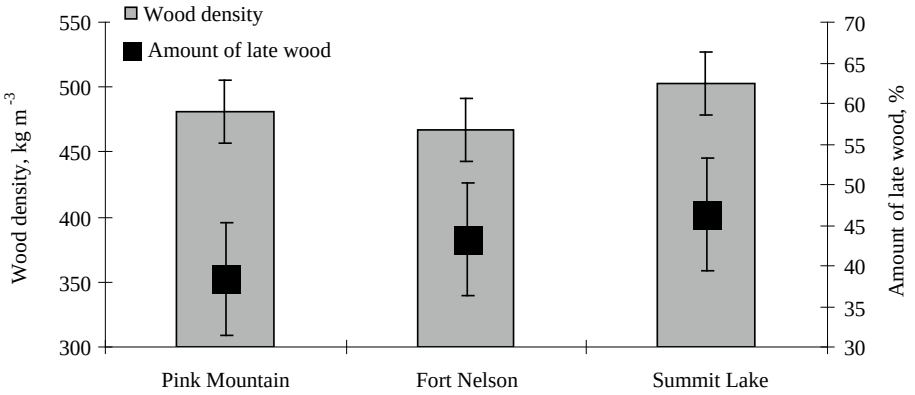

Figure 2. Amount of late wood and density values of lodgepole pine provenances (error bars show standard deviation of mean values).

Table 1

Chemical composition of lodgepole pine wood of different provenances

	Cellulose content, %	Std	Lignin content, %	Std	Extractives content, %	Std	Ash content, %	Std
Pink Mountain	48.7	1.2	26.4	0.8	2.4	0.6	0.3	0.01
Fort Nelson	48.4	0.8	26.4	0.7	2.3	0.7	0.3	0.01
Summit Lake	49.7	1.1	26.3	0.5	2.9	1.2	0.2	0.04

provenance wood with significantly ($p<0.05$) higher density 503 kg m^{-3} overtook Pink Mountain (481 kg m^{-3}) and Fort Nelson (467 kg m^{-3}) samples. Also amount of latewood differed between wood samples. The highest result (36-57%) was observed for Summit Lake samples as compared to Pink Mountain (32-43%) and Fort Nelson (34-54%) pine wood. Not statistically verified, but still visible (Figure 2) correlation among provenances between the amount of latewood and wood density was established.

Analysis of chemical composition of examined samples revealed significant ($p<0.05$) differences in the content of cellulose (Summit Lake sample with result 49.7% was superior to two other provenance's samples), but in cases of lignin and extractives content (see Table 1) no distinctions came out between Pink Mountain, Fort Nelson and Summit Lake samples.

Results of pulping process (Figure 3) revealed significant effect ($p<0.05$) of trees' provenance on pulp yield and set Summit Lake with pulp yield 48.0% as prevailing over Pink Mountain and Fort Nelson with lower numbers (45.8 and 46.8% respectively). Residual lignin content in pulp varied slightly between provenances (4.4 – 5.0%) and accordingly, significant effect of trees' provenance on lignin content in pulp wasn't observed.

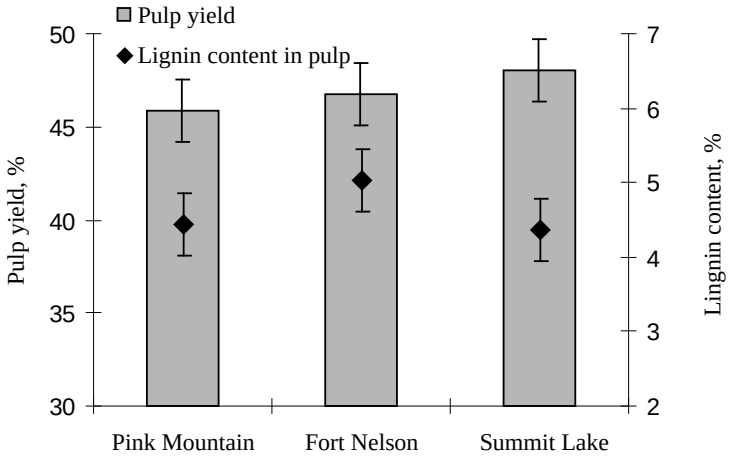

Figure 3. Kraft pulping results of lodgepole pine from different provenances (error bars show standard deviation of mean values).

Study of kraft pulp fibres dimensions showed significant differences in fibre length and shape between the provenances. Distribution (Figure 4) of fibre dimensions indicated Pink Mountain sample as provenance with shorter (2.1 mm) and narrower (31.1 µm) fibres in comparison to Fort Nelson with longer (2.3 mm) and Summit Lake with slightly wider (32.6 µm) fibres.

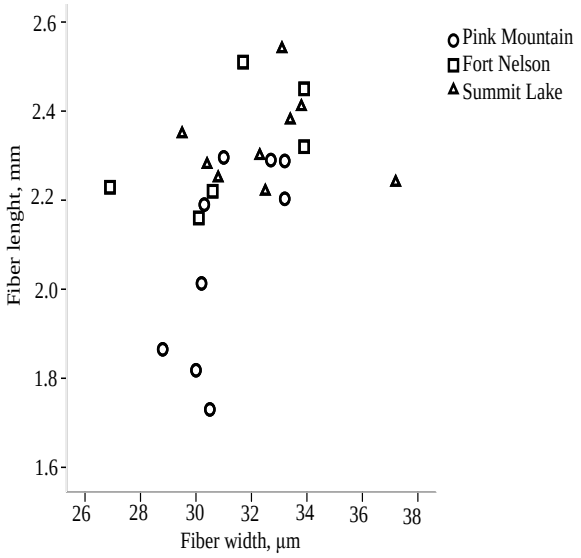

Figure 4. Kraft pulp fibres' dimensions of lodgepole pine from different provenances.

Fibre properties, previously discussed and also reflected in Table 2, are responsible for paper quality and strength parameters. Trees' provenance had varied effect on shape factor, amount of fines in pulp and coarseness. There were considerable ($p<0.05$) differences in shape factor values, where Summit Lake sample showed higher results over Fort Nelson and in coarseness measurements, the result of Summit Lake was higher than that of Pink Mountain.

Table 2

Kraft pulp fibres' properties of lodgepole pine from different provenances

	Shape factor, %	Amount of fines in pulp, %	Coarseness, mg m^{-1}
Pink Mountain	93.3	1.9	149
Fort Nelson	92.6	1.6	165
Summit Lake	93.8	1.8	177

Figure 5 reflects handsheet strength properties of the investigated pulp samples. Calculations of data showed significant ($p<0.05$) effect of trees' provenance on all parameters, except burst index, where no considerable differences between the samples were found. Pink Mountain provenance surpassed others in all paper strength parameters. Breaking length and tensile index values of Pink Mountain lodgepole pine pulp were higher (3.7 km and 36.7 N m g^{-1} respectively) than that of Summit Lake wood pulp (2.9 km and 28.8 N m g^{-1}). Also, significant differences in stretch indices were observed – Summit Lake samples were noticeably ($p<0.05$) behind others.

Summarizing the data on pulp and handsheet properties, lodgepole pine fibres from Pink Mountain provenance seem to offer paper with more promising properties.

Conclusions

1. When comparing lodgepole pine tree samples from different provenances, Summit Lake pine samples indicated higher wood density, amount of late wood and higher cellulose content when

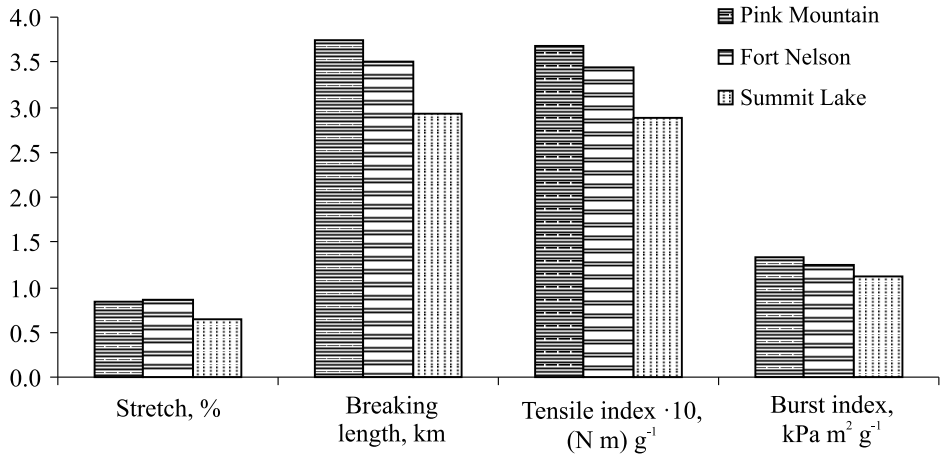

Figure 5. Handsheet strength properties of lodgepole pine from different provenances.

compared to other studied trees' provenances – Pink Mountain and Fort Nelson.

2. Higher kraft pulp yield was observed for lodgepole pine samples from provenance Summit Lake, but no significant differences in residual lignin content in pulp between provenances was noticed.
3. Pink Mountain provenance's pine pulps had shorter and narrower fibres in comparison with other provenances, still in majority of paper strength parameters – breaking length and tensile index - they were in the forefront.

Acknowledgements

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References

1. Elfving B., Ericsson T., Rosvall O. (2001) The introduction of lodgepole pine for wood production in Sweden – A review. *Forest Ecology and Management,* 141, pp. 15–29.
2. Hatfield R.D., Grabber J., Ralph J., Brei L. (1999) Using the acetylbromide assay to determine lignin concentrations in herbaceous plants: Some cautionary notes. *Journal of the Science of Food and Agriculture,* 47, pp. 628–632.
3. Iiyama K., Wallis A.F.A. (1990) Determination of lignin in herbaceous plants by an improved acetyl bromide procedure. *Journal of the Science of Food and Agriculture,* 51, pp. 145–161.
4. Iiyama K., Wallis A.F.A. (1988) An improved acetyl bromide procedure for determining lignin in woods and wood pulps. *Wood Science and Technology,* 22, pp. 271–280.
5. Jansons A., Baumanis I. (2008) Growth and quality of transferred Scots pine (*Pinus sylvestris* L.) provenances in Latvia. *LLU Raksti,* 20 (315), pp. 22–31.
6. Jansons A., Sisenis L., Jansons J. (2009) Provenance differences in above-ground biomass of *Pinus contorta* Dougl. Var *latifolia* Engelm. and *Pinus sylvestris* L. International conference *Research and conservation of biological diversity in Baltic Region,* Daugavpils, Latvia, pp. 58.
7. McLane S.C., Daniels L.D., Aitken S.N. (2011) Climate impacts on lodgepole pine *(Pinus contorta)* radial growth in a provenance experiment. *Forest Ecology and Management,* 262, pp. 115–123.
8. Sable I., Grinfelds U., Jansons A., Vikele L., Irbe I., Verovkins A., Treimanis A. (2012) Comparison of the properties of wood and pulp fibers from Lodgepole pine (*Pinus contorta*) and Scots pine (*Pinus sylvestris*). *Bioresources,* 7(2), pp. 1771–1783.
9. TAPPI Test Methods (2000) TAPPI press, USA, 1484 p.

SCOTS PINE (*PINUS SYLVESTRIS* L.) STEM WOOD AND BARK MOISTURE AND DENSITY INFLUENCING FACTORS

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Abstract
Latvia uses average moisture content and density indexes obtained in Russia and European countries; though, these indexes are different, and there is no information about the most suitable one for conditions in Latvia. Research complex on Latvia's industrially important tree species - Scots pine (*Pinus sylvestris* L.) stem wood and bark moisture and density changes, depending on influencing factors, is being conducted at Forestry Faculty of Latvian University of Agriculture. The research results on Scots pine, obtained during the year 2011 in the whole territory of Latvia, are outlined in this article. Wood and bark moisture and density were analyzed in 21 sampling plots, arranged in middle-aged and cutting-aged reached forest stands, depending on tree age, cutting time and location place in the tree stem. The average moisture content of pine wood mostly depends on heartwood specific weight and age of the tree. With an increase of tree age, average wood moisture content value decreases from 111% (40 years old trees) to 77% (145 years old trees). Scots pine heartwood moisture content changes a little during the year: 30– 34% for 71 to 146 years old trees; and 34-41% for 37–70 years old trees. Sapwood moisture content changes from 113% (in the summer) to 130% (in the winter), without any reference to the age of the tree. The average density of oven dry timber obtained from 71–146 years old trees in the research is 0.501 g cm^{-3}, whereas in freshly cut condition – 0.848 g cm^{-3}.
Key words: Scots pine wood, bark, moisture, density.

Introduction

The term moisture content is expressed as the amount of water in the wood that is water percentage of wood mass. To reconcile wood moisture content of different species, absolute humidity of wood is used, which characterizes relation of water mass in wood in comparison with mass of oven dry timber (Vaņins, 1950).

Wood density depends on several factors. The most important of those is wood moisture content. Wood always contains certain amount of water. When water content in wood changes, wood density also changes (Ozoliņš, 2005).

Moisture content and density of wood and bark are interconnected and very important physical and technological indicators. These factors have influence on transportation of wood, workability, durability, drying process, calorific heat value and on other physical parameters. Wood moisture content and density mainly influences conversion coefficients, which are used for quantity assessment of round timber.

Moisture content and density are not allocated evenly neither in the longitudinal direction of the stem, nor in the direction from stem heart to bark. It differs from species, months and depends on the age of the tree, meteorological, climatic and other conditions.

Wood density dependence on the geographical growing position was clarified by several researchers in Norway, Sweden, Scotland and France. It has been observed that wood density increases more if the tree grows southwards (Hedenberg, 2003).

As a few local researches have been carried out, necessary indexes of wood moisture content and density have not been rated in Latvia for practical industrial needs, but generalization of information, obtained in other countries, is used instead. That is the reason why such research would be important for Latvia. The aim of this research is to determine wood moisture content and density ratio for the most important industrial wood species in Latvia – Scots pine (*Pinus silvestris* L), as well as to determine factors that affect these indicators.

Latvia uses average moisture content and density indexes obtained in Russia and European countries, but they are mutually different, and there is no information about the most suitable one for conditions in Latvia. Therefore, it is necessary to carry out research in Latvia, and, accordingly, the aim of the research is to find out wood moisture content and density parameters for the most industrially important tree species, as well as to find their influence factors. Pine wood and bark moisture content and density research results, acquired in the first year of investigations, are described in this article.

Materials and Methods

The research results on Scots pine were obtained during the year 2011. To assess the influence of climatic and growing conditions, sampling plots were established throughout the whole territory of Latvia. Sampling plots were placed in the most common growing site types of Scotch pine: *hylocomiosa* (7 sample plots), *myrtillosa* (6 sample plots), *vacciniosa* (1 sample plot), *myrtillosa mel.* (6 sample plots) and *myrtillosa turf. mel*. (1 sample plot).

Sampling plots are located in commercial thinning forest stands, and in the final felling forest stands,

once for every month. Sampling plots are arranged in the stands where the proportion of pine is at least 60%. Plots are arranged in the harvester felling area strip most properly representing this forest stand.

Ten sample trees, with a certain step, and by regular arrangement, are chosen in the established sampling plot, for obtaining sample discs (every disc thickness equals to 5 cm). Sample trees are taken proportionally to the distribution of tree amount in diameter classes. Sample discs are taken during the harvesting, starting from the tree stem butt end and further, from every log, sawn by a tree harvester.

Subsequently diameter of sample disk in mm is measured in two mutually perpendicular directions both over and under the bark. Then each sample disk is divided in four pieces, and one sample is chosen for further processing from each piece and sawn out in 30 degree angle clockwise (Figure 1). Each sample is marked with tree numbers, for example 1-2-3, where:

- 1 – sample tree number;
- 2 – sample disk sequence in growth direction;
- 3 – piece number.

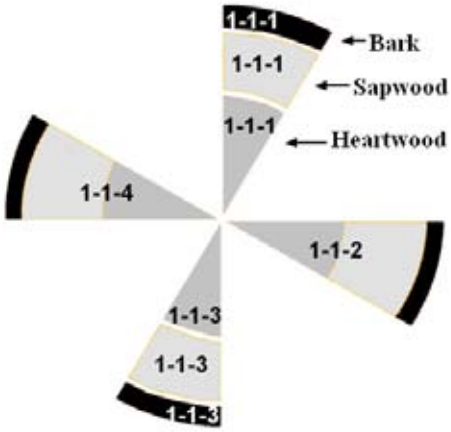

Figure 1. Segment selection.

Two samples (second and fourth in this case) are left untouched, but from other two ones the sapwood is separated from bark and heartwood (the first and the third sample), as shown in Figure 1.

Weight and volume of wood and bark samples is measured in fresh cut condition right after sawing. Weight is obtained by electronic scales, but volume is measured by immersing method. Volume equals to the amount of water, displaced by the sample. Volume of the bark samples is calculated on the basis of measuring the length, width and thickness.

Afterwards samples are placed into the drying oven at 103 °C until samples are oven dry. Weight and volume is measured again when samples are dry.

Absolute moisture indicator is used for wood and bark characterization. That is the amount of water weight in wood and bark, shown as percentage of dry wood and bark weight (Formula (1)).

$$W_a = \frac{m_1 - m_2}{m_2} \times 100, \quad (1)$$

where:
W_a – absolute moisture content of wood and bark, %;
m_1 – sample mass in humid condition, g;
m_2 – sample mass in dry condition, g.
Wood and bark density in freshly-cut and dried condition is calculated by Formula (2):

$$\rho_w = \frac{m_w}{V_w}, \quad (2)$$

where:
ρ_w – wood and bark density, g cm^{-3}, at corresponding wood moisture;
m_w – mass of the sample, g, at corresponding wood moisture;
V_w – volume of the sample, cm^3, at corresponding moisture.

To determine whether moisture content and density vary considerably depending on age, t-test with program SPSS is accomplished and p – value, at significance level $\alpha = 0.05$, is calculated. If p - value $<\alpha$, then the moisture differences are significant.

In order to determine correlation, the correlation coefficient was calculated. Correlation analysis is to determine the closeness of the relationship between the factorial and the resulting feature. If the correlation coefficient of $r \leq 0.5$ the correlation is weak; if $0.5 < r \leq 0.8$ the correlation is moderately close; if $r > 0.8$ the correlation is strong. Correlation coefficient critical values are read from the table after the iteration number.

Results and Discussion

Scots pine sapwood moisture content significantly differs from heartwood moisture content - sapwood moisture content is 3-4 times higher than of heartwood. It is shown in Table 1.

As shown in Table 1, only for sapwood $p>\alpha=0.05$, and this means that the moisture content of sapwood has no significant differences according to age, but for other parts of the tree stem cross section $p<\alpha=0.05$, which means that moisture difference is significant according to the age of the tree.

Moisture content of Scots pine heartwood varies little for a year-long period. A study conducted for Scots pine of age from 37 to 70 years reveals that moisture content varies from 34% to 41%, but for 71–146 years old trees the value of this index is between

Table 1

Moisture content of Scotch pine, depending on the age of the tree

Part of the cross-section	Wood and bark moisture content, %				p – value ($\alpha = 0.05$)
	37 – 70 years	Std. Deviation	71 – 146 years	Std. Deviation	
Heartwood	37.3	4.4	32.0	2.9	0.000
Sapwood	121.3	11.9	122.4	13.1	0.606
Wood, average	108.4	11.9	90.6	10.1	0.000
Crust bark	141.2	38.5	99.4	33.8	0.000
Flaky bark	194.7	36.9	181.0	36.7	0.000
Bark average	156.0	32.3	119.4	27.4	0.000
Wood and bark	110.5	13.8	92.9	11.8	0.000

30 and 34%. Yearly fluctuations of sapwood moisture content are higher. Sapwood moisture content of 37–70 years old trees varies from 113% (in August) to 130% (in April), but for 71–146 years old trees sapwood moisture content varies from 116% (in September) to 130% (in February). The average moisture content of Scots pine wood mainly depends on proportion of heartwood and tree age.

Moisture content of Scots pine sapwood is 133%, but moisture content of heartwood is 31%, according to the study conducted in Germany. It is also shown that there is a big difference between early wood moisture (220%–226%) of sapwood and late wood moisture (58%–68%) of sapwood. In conclusion, sapwood average moisture content is affected by early wood and late wood ratio (Trendelenburg, 1939).

According to the data, obtained in St. Petersburg area from 70 to 90 years old Scots pines, sapwood moisture content is 122%; and heartwood moisture content is 33%, but average value for wood is 90% (Vaņins, 1950).

Data values, obtained in Latvia, differ more from those, which have been reported for Germany, than from the St. Petersburg region data. This could be explained by more similar climate and growing season length in Latvia and in the St. Petersburg' region.

Tree stem wood moisture content of the same tree species depends on the tree age. Wood moisture content of young trees is slightly higher than that of old trees. Besides that, yearly moisture fluctuations (the difference between moisture maximum and minimum values) for young trees are much higher than for the old ones (Vaņins, 1950).

As it is shown in Figure 2, with an increase of tree age, average wood moisture content value decreases from 111% (40 years old trees) to 77% (145 years old trees). The correlation coefficient ($r=0.653 > r_{0.05}=0.138$) indicates to the moderately close correlation between the average wood moisture content and tree age.

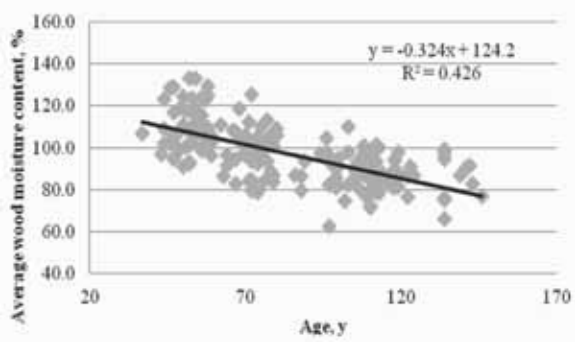

Figure 2. Average wood moisture content depending on tree age.

Average wood moisture content changes, depending on the tree age, could be explained by the heartwood part proportion.

Scots pine heartwood proportion also depends on the tree age. When a tree grows older, its heartwood proportion increases. With the tree diameter increase from 15cm to 30cm, the proportion of its heartwood increases to 67%. With the tree age increase from 60 to 129 years, its heartwood part increases from 21% to 41%; therefore, the average tree stem wood moisture content reduces. Assuming that sapwood moisture content is 131% and heartwood moisture content is 31%, the average moisture content of Scots pine wood would decrease from 110% to 90% when the tree grows older from 60 to 129 years (Gjerdrum, 2003).

As shown in Figure 3, with the tree age increase from 40 to 145 years, its heartwood part increases from 14% to 49%. Correlation coefficient value ($r=0.786 > r_{0.05}=0.138$) indicates to a moderately close correlation between heartwood proportion and the tree age.

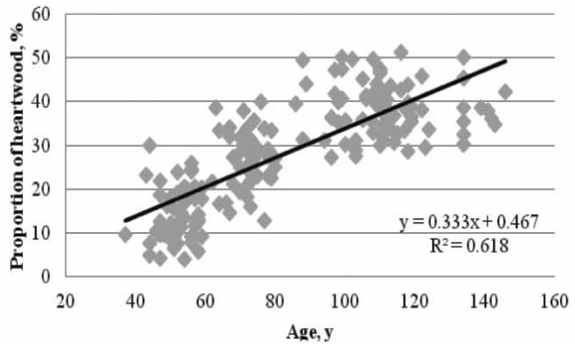

Figure 3. Tree stem heartwood proportion depending on tree age.

It has been observed that the average wood moisture content gradually decreases from butt up to the middle of the trunk for conifers, but the moisture gradually increases at the top part (Pong, 1986).

Summarizing yearly study results for the Scots pine, in the direction from the stem butt-end, average moisture content decreases to ¼ from stem length, but, with the further increasing of distance from the stem butt-end, moisture content increases, too.

Sapwood moisture content for 37–70 years old trees throughout the whole tree stem is increasing from 113% to 146%, and, to ¼ from stem length, the average wood moisture content is decreasing (from 99% down to 88%), but in the tree stem top part the average wood moisture content increases to 146%. Heartwood moisture content increases to 2/3from the stem length (from 36% up to 39%).

Sapwood moisture content of 71–146 years old trees increases throughout the stem from 111% to 137%, average wood moisture reduces to ¼ from the trunk length (from 82% up to 77%), but in the tree top part it increases to 129%. Heartwood moisture content throughout the stem is increasing from 31% to 33%.

Bark moisture content for 71–146 years old trees throughout the stem increases from 91% in the tree butt-end part to 190% in the tree top part. Bark moisture content for 37-70 years old trees throughout the stem increases from 132% in the butt part to 201% in the top part.

Correlation coefficient value $r=0.714 > r_{0.05}=0.138$ (71-146 years old trees) and $r=0.593 > r_{0.05}=0.138$ (37–70 years old trees) indicates to the moderately close correlation between the bark moisture content and location on the trunk.

Another important indicator is wood density. It describes the amount of woody tissue per volume unit, so it is closely related to the values of other wood physical and mechanical properties and their logic mutual relevance. Wood density is an important characteristic feature, related with its quality. Higher mechanical strength characteristics are expected for denser wood (Орлов, 1960).

Freshly harvested timber and bark density can also be used as a conversion factor (t m^{-3}), used for round timber quantitative estimation (Līpiņš and Liepa, 2007).

The easiest method for determining the round timber volume is mass or weighting method, which is widely used method in many countries. There is a strong correlation between round timber weight and volume (Līpiņš et al., 2011).

Wood density depends on several factors. The most important of those is wood moisture content. Wood always contains certain amount of water. Wood density varies according to water content change in wood (Ozolinš, 2005).

Wood is heavier in freshly cut condition, but it becomes lighter during drying. In order to compare density of two or more wood species, density index always has to be determined at the fixed moisture content – for wood at oven dry condition, at 12% moisture content and in freshly harvested conditions (Уголев, 2001). Density parameters by B.N. Ugolev and parameters obtained in our research are compared in Table 2.

It can be seen that results in our study differ from those, which are being reported by B.N. Ugolev. Wood density indices obtained in our research exceeds

Table 2

Wood and bark density depending on the moisture content

Data source	Wood and bark density, g cm^{-3}							
	Oven dry condition (W=0%)			Basic moisture (W=12%)		Freshly cut condition		
	Wood	Crust bark	Flaky bark	Wood	Bark	Wood	Crust bark	Flaky bark
Research	0.501	0.412	0.532	0.529	–	0.848	0.651	0.844
B.N. Ugolev (Б.Н. Уголев)	0.470	0.650		0.500	0.680	0.863	0.850	

B.N. Ugolev results by 6.2% in the case of oven dry wood density, by 5.5% in the case of wood density at basic moisture content, and only by 1.7% in the case of freshly-cut wood conditions. Bark is denser in the results of B.N. Ugolev. Only in freshly cut condition flaky bark was as dense as in the results of B.N. Ugolev.

Research on the wood density changes according to geographic disposition has been done in Norway, Sweden, Scotland and France. Correlation - wood density, wood fibre length and width increase in the direction from north to south (Hedenberg, 2003) was observed.

In some recent scientific researches the tree age rather than growing conditions has been chosen as the most important selection criterion. In these studies it was concluded that wood density and wood growth conditions do not correlate with each other (Hedenberg, 2003).

As the main reason for wood density difference, which is connected with geographical disposition, the difference in growth conditions has been referred to. The geographical longitude and latitude affect wood density because of the different soil structure in each place, the amount of thaw periods during the winter, growing season length -, all this together influence early and late wood ring width, which in turn affects the wood density (Plotnikoff et al., 2000).

The research findings difference from B.N. Ugolev data could be explained by the fact that B.N. Ugolev density parameters are obtained in Russia where the climate is continental.

Wood density depends not only on tree species, but also on the tree age. Swedish research found that the pine wood density of oven dry wood increases by increasing of tree age (Atmer and Thörnqvist, 1982).

Also, in research there is an evidence about previously detected connection that by increasing of tree age increases wood, especially heartwood, density – by 14.5%. For bark - both flaky and crust type, regarding the tree age, density remains practically unchanged (Table 3).

As shown in Table 3, for sapwood, crust bark, flaky bark and bark average $p > \alpha = 0.05$, and this means that for these parts of the tree stem cross-section, density of oven dry conditions does not have any significant differences according to the tree age, but for the heartwood, wood average, and wood and bark together $p < \alpha = 0.05$, and this means that the density differences of oven dry conditions are significant depending on tree age.

In Finland 40–60 years old Scots pine stands, oven dry wood density changes throughout the stem are significant. Scots pine wood density is decreasing in the direction from the butt-end part to the top part from 460 g cm^{-3} down to 360 g cm^{-3} (Repola, 2006).

Oven dry Scots pine wood density of 71–146 years old trees throughout the stem is decreasing from 0.550 g cm^{-3} in the butt part up to 0.447 g cm^{-3} in the top part.

Oven dry Scots pine wood density of 37-70 years old trees is decreasing from 0.519 g cm^{-3} in the butt-end part to 0.417 g cm^{-3} in the top part. Correlation coefficient values $r=0.623 > r_{0.05}=0.138$ (71–146 years old trees) and $r=0.616 > r_{0.05}=0.138$ (37-70 years old trees) indicate on moderately close correlation between absolutely dry wood density and location on the trunk.

Oven dry Scots pine bark density throughout the stem increases from 0.385 g cm^{-3} in the butt-end part to 0.575 g cm^{-3} in the top.

Bark density changes in oven dry condition throughout the stem between trees of different ages are not significant. Correlation coefficient value $r = 0.546 > r_{0.05} = 0.138$ indicates on moderately close correlation between oven dry bark density and location on the trunk.

Table 3

Pine wood and bark density in oven dry condition depending on tree age, g cm^{-3}

Part of the cross-section	Wood and bark density in oven dry condition				p – value ($\alpha = 0.05$)
	37 – 70 years	Std. Deviation	71 – 146 years	Std. Deviation	
Heartwood	0.421	0.056	0.492	0.052	0.000
Sapwood	0.490	0.033	0.504	0.042	0.024
Wood average	0.478	0.032	0.501	0.040	0.000
Crust bark	0.413	0.070	0.412	0.081	0.744
Flaky bark	0.539	0.074	0.532	0.091	0.279
Bark average	0.424	0.052	0.421	0.052	0.605
Wood and bark	0.470	0.032	0.497	0.041	0.000

Table 4

Pine wood and bark density in freshly-cut condition that depends on tree age, g cm^{-3}

Part of the cross-section	Wood and bark density in freshly-cut condition, g cm^{-3}				p – value ($\alpha = 0.05$)
	37 – 70 years	Std. Deviation	71 – 146 years	Std. Deviation	
Heartwood	0.516	0.069	0.585	0.059	0.000
Sapwood	0.956	0.047	0.988	0.055	0.000
Wood average	0.881	0.064	0.848	0.062	0.001
Crust bark	0.697	0.074	0.604	0.082	0.000
Flaky bark	0.864	0.093	0.844	0.095	0.082
Bark average	0.730	0.097	0.651	0.071	0.000
Wood and bark	0.873	0.051	0.846	0.053	0.002

In the research it was found out that by an increase in tree age, wood density in freshly-cut condition is increasing – heartwood density increases by 11.8%, sapwood density increases by 3.2%, but on average wood density decreases by 3.7%. Higher average wood density for younger trees (37–70 years old) can be explained by a small proportion of heartwood. Crust bark for younger trees is by 13.3% denser and flaky bark is by 2.3 % denser (Table 4).

As shown in Table 4, only for flaky bark $p>\alpha=0.05$ and that means that density differences in oven dry condition are not significantly depending on the tree age, but for the other parts of cross section $p<\alpha=0.05$ and that means, that density differences in fresh cut condition are significantly depending on the tree age.

Scotch pine average wood density in fresh cut condition from the butt-end part gradually decreases to the middle part of the trunk, but in the top part there is a gradual increase in density.

Sapwood density of 37–70 years old trees throughout the stem decreases from 0.981 g cm^{-3} to 0.916 g cm^{-3}. The average wood density decreases till the middle part of the trunk from 0.899 g cm^{-3} up to 0.821 g cm^{-3}, but in the top it increases to 0.916 g cm^{-3}. Heartwood density throughout the stem is decreasing to 2/3 of the stem length from 0.586 g cm^{-3} to 0.479 g cm^{-3}.

Sapwood density of 71–146 years old trees throughout the stem decreases from 1.011 g cm^{-3} to 0.948 g cm^{-3}. The average wood density decreases till the middle part of the trunk from 0.889 g cm^{-3} to 0.776 g cm^{-3}, but in the top part there is an increase to 0.915 g cm^{-3}. Heartwood density throughout the stem is decreasing from 0.668 g cm^{-3} to 0.505 g cm^{-3}.

Bark density in fresh cut condition of 71–146 years old trees throughout the stem is increasing from 0.565 g cm^{-3} in the butt part and up to 0.899 g cm^{-3} in the top part, but for 37–70 years old trees throughout the stem it is increasing from 0.668 g cm^{-3} in the butt-end part and to 0.888 g cm^{-3} in the top part. Correlation coefficient values r=0.697 (71–146 year old trees) and $r=0.551 > r_{0.05}=0.138$ (37–70 year old trees) indicate on moderately close correlation between absolutely dry bark density and the place on the trunk.

Conclusions

1. The average moisture content of pine wood mostly depends on heartwood specific weight and age of the tree. With an increase of tree age, average wood moisture content value decreases from 111% (40 years old trees) to 77% (145 years old trees).
2. Pine heartwood moisture content changes a little during the year: 30–34% for 71 to 146 years old trees; and 34–41% for 37–70 years old trees. Sapwood moisture content changes from 113% (in the summer) to 130% (in the winter), without reference to the tree age.
3. The average density of oven dry timber obtained for 71–146 years old trees in the research is 0.501 g cm^{-3}, in freshly cut condition - 0.848 g cm^{-3}, but the average density of wood and bark in oven dry timber is 0.500 g cm^{-3}, in freshly cut condition - 0.846 g cm^{-3}. The average density of oven dry timber obtained for 71–146 years old trees is 0.478 g cm^{-3}, in freshly cut condition - 0.881 g cm^{-3}, but the average density of wood and bark in oven dry timber is 0.470 g cm^{-3}, in freshly cut condition - 0.873 g cm^{-3}.
4. The wood density of oven dry pine for 71–146 years old trees decreases from 0.550 g cm^{-3} (butt-end) down to 0.447 g cm^{-3} (top-end), but for 37-70 year old trees from 0.519 g cm^{-3} down to 0.417 g cm^{-3}.

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References

1. Atmer B., Thörnqvist T. (1982) The Properties of Tracheids in Spruce (*Picea abies*) and Pine (*Pinus silvestris*). The Swedish University of Agricultural Sciences, Department of Forest Products, Report no 134, 59 pp.
2. Gjerdrum P. (2003) Heartwood in relation to age and growth rate in *Pinus sylvestris* L. in Scandinavia. *Forestry*, 76(4), pp. 413–424.
3. Hedenberg Ö. (2003) Differences in wood and fibres properties (Regions, stands, trees and parts of tree models). Available at: http://www.innventia.com/upload/10405/d4-3_stfi-hedenberg.pdf, 12 February 2011.
4. Līpiņš L., Liepa I. (2007) *Apaļo kokmateriālu uzmērīšana* (Round wood measurement), LLU Meža fakultāte, Jelgava, 104 lpp. (in Latvian).
5. Līpiņš L., Sarmulis Z., Millers M. (2011) Cik blīva un mitra ir Latvijas koksne (How dense and moist is Latvian wood). *Baltijas Koks*, Nr.4. 28–29. lpp. (in Latvian).
6. Ozoliņš A. (2005) *Praktiskā koksne* (Practical wood), Jumava, Rīga, 96 lpp. (in Latvian).
7. Plotnikoff M.P., Schmidt M.G., Bulmer C.E. (2000) Retrospective studies of soil conditions and forest productivity on rehabilitated landings: Interior of British Columbia. In: *Proceedings from science to management and back*: a science forum for southern interior ecosystems of British Columbia. Southern Interior Forest Extension and Research Partnership, Kamloops, B.C., pp. 113–117.
8. Pong W.Y., Waddell D.R., Lambert M.B. (1982) Wood Density-Moisture Profiles in Old-Growth Douglas-Fir and Western Hemlock. Available at: http://www.fs.fed.us/pnw/pubs/pnw_rp347.pdf, 12 February 2011.
9. Repola J. (2006) Models for vertical wood density of Scots pine, Norway spruce and birch stems, and their application to determine average wood density. *Silva Fennica*, 40(4), pp. 673–685.
10. Trendelenburg R. (1939) *Das Holz als Rohstoff* (*Wood as material*), Lehmans Verlag, München, Berlin, 43 S. (in German).
11. Vaņins S. (1950) *Koksnes zinātne* (*Wood Science*), Latvijas valsts izdevniecība, Rīga. 464 lpp. (in Latvian).
12. Орлов Д.М. (1960) *Древесина и древесные материалы* (*Wood and Wood products*), Гослесбумиздат, Москва, 98 с. (in Russian).
13. Уголев Б.Н. (2001) *Древесиноведение с основами лесного товароведения* (*Wood with the Fundamentals of Forest Commodities*). Московский государственный университет леса, Москва, 310 с. (in Russian).

RESEARCH OF ′DURATION OF LOAD′ EFFECTS IN TIMBER ELEMENTS IN BENDING

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Abstract
The Duration of Load (DOL) effect is the combined influence of the mechanical loading history and climatic history on the strength of materials. DOL effect is one of the most important characteristics of wood and wood-based materials. The material degradation or damage induces strength reductions. Creep is one of the most important effects of DOL. Creep is a phenomenon that negatively affects functional compliance, behavior and strength of timber structures in extended years of exploitation. The creep phenomenon is affected by surrounding temperature, relative humidity, timber moisture content and other factors. The study aimed to establish a correct factor system for accurate prediction of long-term deformations of timber structures that is corresponding to environmental conditions and timber properties in the region of Latvia. The experimental research was made in Jelgava, Latvia, and represents timber beam four-point long-term loading in bending with variable cross section height-span length ratio under uncontrolled climatic conditions. There were 12 timber beams with two different span lengths – 1.32 m and 1.50 m used. The timber beam cross section dimensions: height – 60 mm, width – 30 mm. The timber beams were not dried and the moisture content at the start of the experiment varied from 19% to 33%. The applied load values – 0.40 kN and 0.31 kN. Moisture content fluctuations and negative air temperature accelerated creep development and intensity. Prediction of final long-term deformations should rate not only the type of timber material and service class but the strength class, too.
Key words: Duration of Load, creep phenomenon, long-term loading, height-span length ratio.

Introduction

Molecular structure of wood is a very complex system with uneven distribution of molecules. J. Bodig and B.A. Jayne (1982) found that wood has very manifold physical and mechanical properties because of its anisotropy and fibrous structure which needs to be taken into consideration when using wood in construction. Wood structure is the reason why mechanical and physical properties of wood are significantly affected by the surrounding environment. Wood adapts to the environment in which it is located. This process is called hygroscopicity – material ability to absorb moisture from the surrounding environment. During this process, the water molecules penetrate into the wooden molecules that physically alter the material. Heterogeneous structure of wood with a high level of hygroscopicity causes swelling and cracking of the material. Climatic variability and, in particular, a large amount of moisture content changes has a very negative impact on the wooden constructions in long-term loading.

Increasing of moisture and durability of the load combination effect in time leads to reduction of the strength of a timber. This effect known as DOL (Duration of Load) effect is one of the most important characteristics of wood and wood-based materials.

For the first time the idea of different short-term and long-term timber loading behavior was expressed by the French naval architect George Louis Le Buffon (1740). He observed the behavior of structural oak beams under long-term bending load and concluded that the maximum long-term load in bending should not exceed 50% of the short-term strength.

When loading timber structures with long-term constant load, deflection increases over time. This process is called ′creep′. Creep is deformation increase at constant load (Schniewind, 1968).

S. Thelandersson (1995) and D.G. Hunt (1999) proved that work in linearly elastic phase and creep phenomena are the most basic wood mechanical properties. Serviceability (deflection) requirements are often the main to determine the size of the beam cross section dimensions, if they are subject to long-term and permanent load.

Over time, as a result of creep development, wooden structures do not longer fulfill the serviceability requirements, deflections become unacceptably large and, in the worst case, the construction even loses its load-bearing capacity and collapses. Creep is a ′time-dependent′ deformation. Under long-term load, at low stress levels and under normal moisture and temperature conditions, wood behaves in linear manner. L.R.J. Whale (1988) and P. Morlier (1994) stated that at a higher level of stress and/or under changing environmental conditions, wood shows non-linear correlation between stresses and deformations.

The goal of this study is to establish a correct factor system for accurate prediction of long-term deformations of timber structures that is corresponding to environmental conditions and timber properties in the region of Latvia.

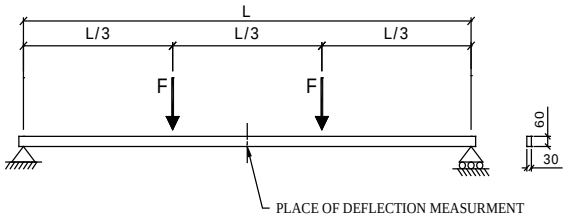

Figure 1. Test model of experiment.

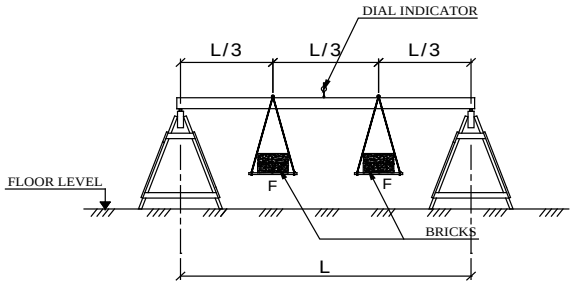

Figure 2. Timber beam loading.

Materials and Methods

The experimental creep test was started in December 2011 in Jelgava, Latvia, and was carried out in a newly constructed house which is not currently populated at this moment. This house was not heated in the winter period; therefore, the climatic conditions were not controlled in any way that allowed checking the timber beam creep operation and development in variable climatic conditions of ambient humidity and temperature.

The experimental creep test at this moment represents long-term loading of twelve (free of knots) pinewood (*Pinus sylvestris* L.) beam in four-point bending. The loading scheme is given in Figure 1. The timber beam cross section nominal dimensions (height and width) – 60 mm and 30 mm. During the whole test it is planned to load timber beams with four different span lengths – a) 1.08 m, b) 1.20 m, c) 1.32 m and d) 1.50 m, but at this moment only two types of span length c) 1.32 m (group of beams KS-3) and d) 1.50 m (group of beams KS-4) are loaded with long-term load.

Concentrated forces were represented by clay and silicate bricks which were suspended on timber beams (Figure 2). The deflection measurements were made with dial indicators. Measuring precision of indicators – 0.01 mm. Measuring diapason of indicators – 50 mm. The dial indicators were placed in the middle of the span on the compressed side of the beam. The environmental climatic condition parameters were recorded once in the day. Temperature (T, °C) in the room and outdoors was fixed with mercury-in-glass (Hg) type thermometers.

The timber beams were loaded in four-point bending with two concentrated forces that each force was calculated so as instantaneous deflection u_{inst} at the middle of the span does not exceed 1/150 part of the timber beam span length u_{inst} < L/150, where L – timber beam span (cm). The timber beam theoretical calculation of four different span lengths is given in Table 1. Four different timber beam span lengths were chosen to examine how the span to depth ratio (18, 20, 22, and 25) influences creep development. For lumber and glued laminated beams, the European static standard ratio is 18:1 (Morlier, 1994).

Parallel to environmental climatic condition parameter recording, timber beam moisture content (MC, %) and relative humidity (RH, %) recordings were made daily.

In order to judge about the timber beam strength properties, theoretical Modulus of Elasticity (MOE) was calculated after registering instantaneous elastic deflection (u_{inst}) immediately (1 minute) after loading. Theoretical MOE (E_{app}) of rectangular cross-section elements, which are loaded in bending with two

Table 1

Timber beam theorethical calculation

Marking	Load (F), kN	Span length (L), m	Design moment (M_d), kNm	Span-heigth ratio Lh^{-1}	Cross section width (b), cm	Cross section heigth (h), cm	Second moment of area about the strong axis (I_y), cm^4	Bending stress $\sigma<1.4$ kN cm^{-2}	Inst. defl. u<L/150 (u_{inst}), cm	Permissible inst. defl. L/150 (u_{perm}), cm
KS-1	0.60	1.08	0.216	18	3	6	54.00	1.200	0.71	0.72
KS-2	0.49	1.20	0.196	20	3	6	54.00	1.089	0.80	0.80
KS-3	0.40	1.32	0.176	22	3	6	54.00	0.978	0.86	0.88
KS-4	0.31	1.50	0.155	25	3	6	54.00	0.861	0.98	1.00

symmetrical concentrated forces, was calculated using equation (1):

$$E_{app} = \frac{F \cdot a}{4 \cdot b \cdot h^3 \cdot u_{inst}} (3 \cdot L^2 - 4 \cdot a^2) \ , \quad (1)$$

where: F – sum of two concentrated forces, kN;
a – distance from support to concentrated force, cm;
L – timber beam span, cm;
b – width of cross section, cm;
h – height of cross section, cm;
u_{inst} – instantaneous deflection, cm.

The creep coefficient c_r in this study is expressed in terms of the initial elastic deflection (u_0):

$$c_r = \frac{u_t - u_0}{u_0} \ , \quad (2)$$

where u_t is the deflection at time (t) in step with the moisture content of wood (MC) and temperature of air (T).

Coefficient of variation (COV) was calculated for mean values of environmental climatic parameters – moisture content, temperature, relative humidity, and relative deflection.

Regression analysis was made for relationship between relative creep c_r and time, and coefficient of determination R^2 was calculated, too.

Results and Discussion

The value of moisture for the twelve loaded beams at the start of the test was variable from 19% to 33% with the mean value of moisture 25.25% with a coefficient of variation (COV) of 19%.

After 64 days of test, the moisture content exhibited a mean value of 12.17% with a COV of 11%.

The monthly average for outdoor temperature were 3.5 °C (December), -1.1 °C (January), and -10.2 °C (first 17 days of February). The monthly average for indoor temperature ranged from 3.9 °C to - 4.9 °C with a mean value of 0.2 °C.

Monthly average for indoor relative humidity ranged from 55.8% to 76.4% with a mean value of 68.2%.

The sizes of the beam cross-section presented mean values of 30.68 mm in width and 58.36 mm in height. Span to depth ratio for the loaded beams was 22 for the group KS-3, and 25 for the group KS-4. Table 2 represents cross-section dimensions of the loaded timber beams.

Table 3 summarizes the main results for the instantaneous deflections (u_{inst}) and creep deflections (u_{creep}) after 64 days of test. In addition, relative creep deflections after 7 and 64 days of test are given. Values of instantaneous and creep deflections are divided in 3 groups which correspond to accurate loading duration and span length of timber beams. According to Eurocode 5, one week is the limit between short-term and medium-term load duration classes, six months is the limit between medium-term and long-term load duration classes, and 10 years is the limit between long-term and permanent load duration classes.

Relative deflection values after 64 days of test showed that loaded beam behavior under long-term load is very different. A detailed analysis shows that four beams – KS-3.1, KS-3.3, KS-3.10, and KS-4.7 – exhibited a very high value of 1.91, 1.96, 1.84 and

Table 2

Cross-section dimensions of timber beams

Marking	Height (mm)			h_{vid}, mm	Width (mm)			b_{vid}, mm
	h_1	h_2	h_3		b_1	b_2	b_3	
KS-4.10	58.30	57.00	57.80	57.70	30.80	30.40	30.50	30.57
KS-4.9	58.50	60.30	58.40	59.07	31.90	32.30	32.80	32.33
KS-4.8	58.20	58.60	58.50	58.43	30.00	30.80	30.70	30.50
KS-4.7	58.30	58.00	57.70	58.00	30.80	30.20	29.80	30.27
KS-3.10	58.70	58.80	58.50	58.67	31.50	31.40	31.70	31.53
KS-3.9	58.60	58.40	58.70	58.57	30.40	30.50	30.30	30.40
KS-3.8	58.60	58.20	58.50	58.43	32.50	32.10	32.30	32.30
KS-3.7	58.30	58.10	58.10	58.17	29.30	28.10	27.50	28.30
KS-3.5	58.10	58.80	58,50	58.47	32.00	31.80	31.90	31.90
KS-3.3	57.50	58.30	57.90	57.90	27.10	30.00	28.40	28.50
KS-3.2	58.30	58.60	58.40	58.43	30.80	32.00	31.40	31.40
KS-3.1	58.40	58.50	58.40	58.43	31.10	30.20	30.80	30.70

Table 3

Results of instantaneous and creep deflections

Marking	Instantaneous deflection (U_{inst}), mm	Creep deflection ($U_{creep,64}$), mm	Relative deflection after 64 days U_{64}/U_{inst}	Relative deflection after 7 days U_7/U_{inst}	Mean value of inst. deflection ($U_{inst,mean}$), mm	Mean value of creep deflection ($U_{creep,64,mean}$), mm
KS-4.10	8.00	4.28	1.54	1.03	9.50	5.04
KS-4.9	13.00	6.71	1.52	1.05		
KS-4.8	12.00	4.22	1.35	1.11		
KS-4.7	5.00	4.94	1.99	1.14		
KS-3.10	6.00	5.03	1.84	1.16	8.50	5.09
KS-3.9	7.00	4.08	1.58	1.06		
KS-3.8	12.00	5.89	1.49	1.08		
KS-3.7	9.00	5.36	1.60	1.13		
KS-3.3	7.90	7.60	1.96	1.18	6.30	4.24
KS-3.5	7.70	3.01	1.39	1.06		
KS-3.2	4.80	1.95	1.44	0.98		
KS-3.1	4.80	4.40	1.91	1.06		

1.99 for relative deflection u/u_{inst} with a mean value of 1.93. Creep deflection for these four timber beams presented 4.40 mm, 7.60 mm, 5.03, mm and 4.94 mm respectively. The remaining 8 specimens presented relative creep values ranging between 1.35 and 1.60. The relative deflection mean value for all timber beams after 64 days of test presented the value of 1.63 with COV of 14%.

The established relative creep ratio values after 7 days of test ranged between 0.98 (KS-3.2) and 1.18 (KS-3.3) with a mean value of 1.09 with a COV of 5%. The value of the coefficient of variation (COV=5%) testifies that dispersion of the results is small and they are credible.

Relative creep relationships versus time during 64 days are analyzed in Figure 3. The curves of timber beams summarize the relative creep histories for the test beams under long-standing (64 days) load. This diagram shows that the test period of 64 days can be divided in two periods: period A) from the start of the test to the forty second day (1.-42.); period B) from the forty second day to the sixty fourth day (42.-64.). These two periods – A and B – are marked in Figure 3. Creep development speeds of 10 specimens in the period A were very similar, with an exception of two timber beams – KS-4.9 and KS-3.3. Creep developments for these two beams were 0.11 mm day^{-1} and 0.17 mm day^{-1} correspondingly. Nine specimens presented creep development speed values from 0.03 mm day^{-1} to 0.07 mm day^{-1}. The timber beam KS-3.2 showed negative (-0.02 mm day^{-1}) creep development during the period A, which means that, deflection of this beam after loading decreased. The mean value of creep development speed during the period A showed a value of 0.057 mm day^{-1}.

Start of the period B, when rise in creep development speed was registered, represents perfect compatibility with rapid decrease in surrounding air temperature. Fast decrease in indoor relative humidity in this cold period caused a subsequent fall in the moisture content of timber beams.

Creep development speed values of all timber beams during the period B were much higher than in the period A. Two timber beams – KS-3.1 and KS-3.3 – represented creep development speed values of 0.17 and 0.23 mm day^{-1}, other 10 specimens recorded speed values ranged between 0.08 mm day^{-1} and 0.14 mm day^{-1} with a mean value of 0.115 mm day^{-1}.

In this case we can conclude that the registered decrease in air temperature (starting on the 42nd day of test) initiated faster creep development which continued till the 64th day of test. Relative humidity and moisture content depleted together with air temperature, which is demonstrated in Figure 4. Creep development was accelerated because air temperature rapidly decreased to minus 10 °C and water froze in the cells of wood. The period of negative indoor air temperature continued for 23 days (starting from the 43rd day of test). Apparently water in the cells of wood was frozen in this period.

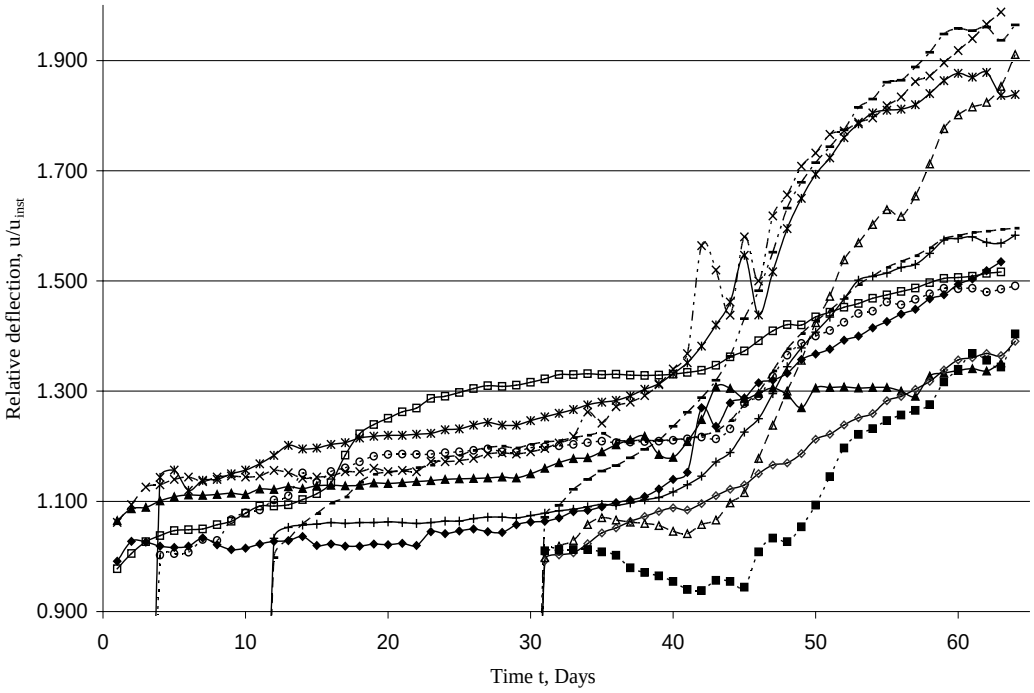

Figure 3. Development of bending creep during 64 days

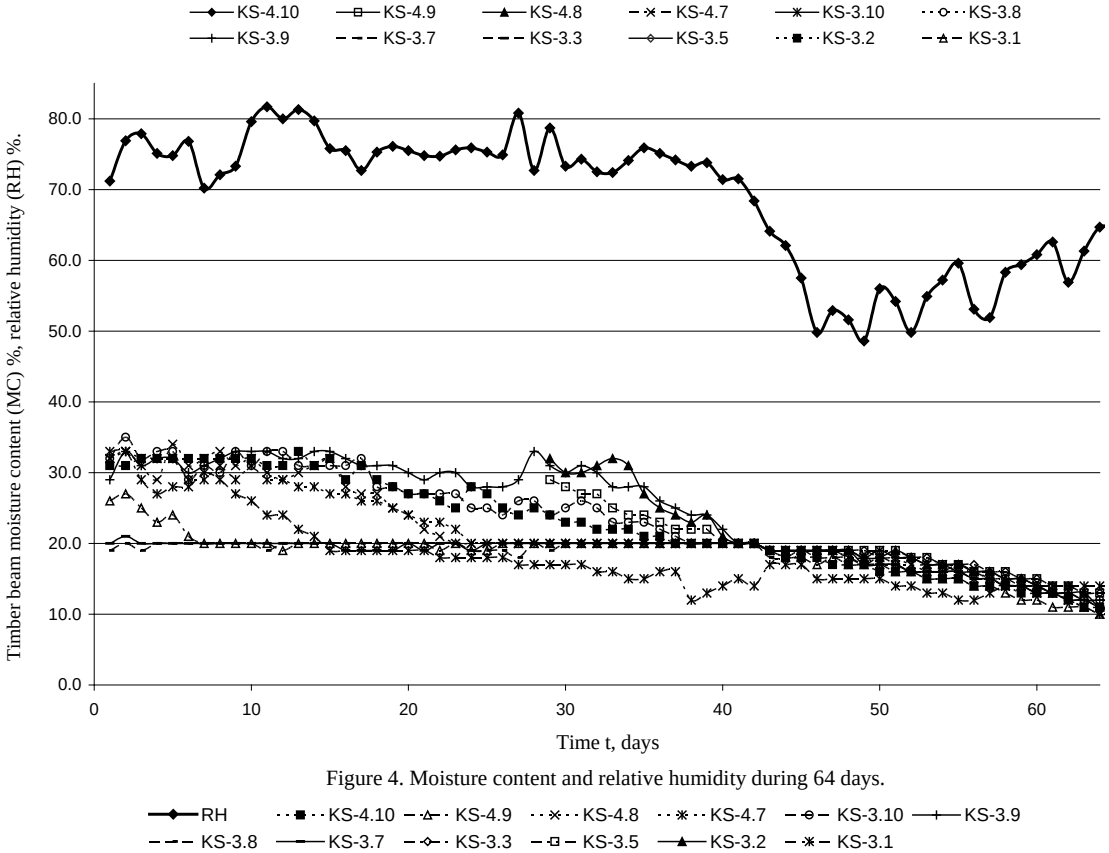

Figure 4. Moisture content and relative humidity during 64 days.

Figure 4 represents hygroscopic behavior of wood – the moisture content of timber beams during air temperature decrease experienced faster drying than it was before this mentioned cycle. Decrease in the moisture content continued even when the rise in air temperature started. The timber beam moisture content at the start of test ranged from 19% to 33% with a mean value of 28%. The mean value of the moisture content of all beams after 64 days was 12.17%.

Table 4

Relative creep c_r of timber beams

Period	Timber beam											
	KS-4.10	KS-4.9	KS-4.8	KS-4.7	KS-3.10	KS-3.9	KS-3.8	KS-3.7	KS-3.3	KS-3.5	KS-3.2	KS-3.1
A	0.12	0.33	0.19	0.31	0.33	0.12	0.21	0.21	0.24	0.09	-0.05	0.05
A+B	0.54	0.52	0.35	0.99	0.84	0.58	0.49	0.60	0.96	0.39	0.40	0.91

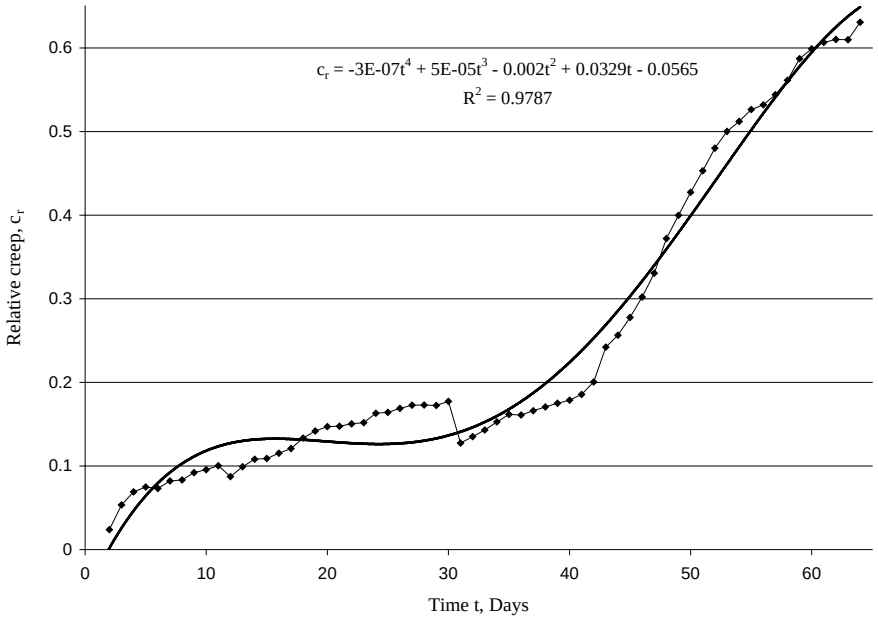

Figure 5 a. Polynomial approximation of average relative creep values versus time under load.

Summary of creep coefficients of all timber beams during the periods A and B is given in Table 4. The analysis of the creep coefficients shows that the period A represents values ranging from -0.05 to 0.33 with a mean value of 0.18.

The creep coefficient values during 64 days of test varied from 0.35 to 0.99. Four timber beams (KS-4.7, KS-3.10, KS-3.3, and KS-3.1) represent creep coefficient values from 0.84 to 0.99, other 8 specimens show values from 0.35 to 0.60. The mean value of creep coefficient c_r during 64 days of test – 0.63.

Different mathematical models were examined to describe the creep relationships according to the

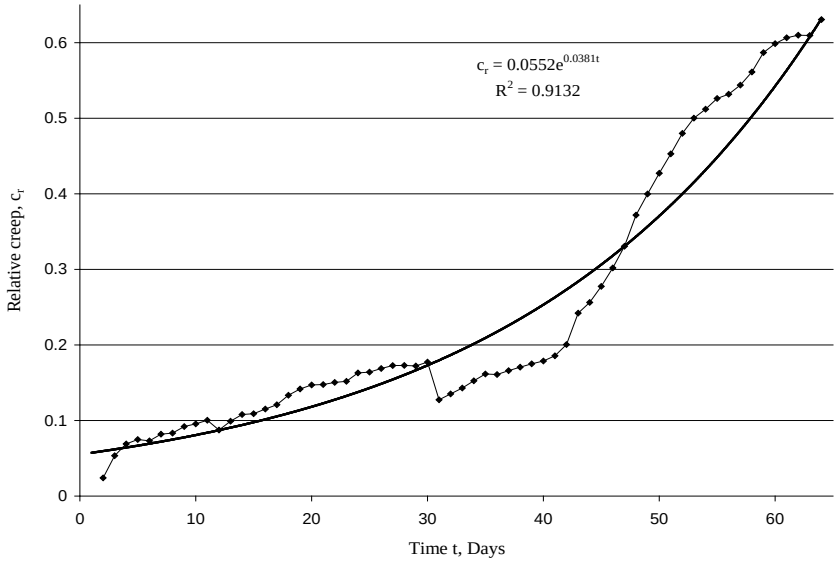

Figure 5 b. Exponential approximation of average relative creep values versus time under load.

test data. Best fitting between the test curve and regression model may be obtained by exponential and polynomial curves. In this study the exponential and polynomial relationships were found as sufficiently good approximations testified by the coefficient of determination R^2 values close to unity (Figure 5a and 5b).

Conclusions

This provisional study provides a background for future experiments in order to establish an accurate factor system for prediction of final deformations in timber structures.

Creep of wood is dependent on season – moisture variation causes fluctuation in creep curves. Relative humidity fluctuations and frozen water in wood cells, which were initiated by radical decrease in air temperature (indoor temperature receded to minus 10 °C), accelerated creep development speed that continued even when constant increase in air temperature was observed. Small cross-section beams are especially influenced by humidity cycling. Small sample size and variability in MOE make it difficult to make more detailed conclusions at this stage of test.

The estimated creep coefficient c_r during 64 days of test presented the mean value of 0.63.

Further studies on wood structure and creep behavior under variable climatic conditions are necessary to adequately judge about all influencing factors. These studies are necessary to accurately predict the final deformations in timber structures corresponding to climatic conditions, type of timber material, service class, and timber strength.

References

1. Bodig J., Jayne B.A. (1982) *Mechanics of wood and wood composites*, Van Nostrand Reinhold, New York, 712 p.
2. Buffon G.L.L. (1740) *Experiences sur la Force du Bois* (Experiments on the strength of wood), Paris L` Academie Royale des Sciences. Histoire et Memoires, pp. 453–467. (in French).
3. Hunt D.G. (1999) *A unified approach to creep of wood*, The Royal Society, 455, pp. 4077–4095.
4. Morlier P. (1994*)* Creep in timber structures. In: *Report of RILEM Technical Committee 112-TSC*. London. 149 p.
5. Schniewind A.P. (1968) Recent progress in the study of the rheology of wood. *Wood Science and Technology*, 2, pp. 188–206.
6. Thelandersson S. (1995) Serviceability limit states - Deformations. In: *Timber Engineering* STEP 1, Centrum Hout, The Netherlands, pp. A17/1–A17/8.
7. Whale L.R.J. (1988) *Deformation characteristics of nailed or bolted timber joints subjected to irregular short or medium term lateral loading*. Ph. D. Dissertation. South Bank Polytechnic, London, U.K, 260 p.
8. EUROCODE 5 – *Design of timber structures – Part 1-1: General – Common rules and rules for buildings*, (2004), Standartizācijas birojs (LVS), Riga, Latvia, 123 p.

LOW-EMISSION HEAT INSULATION FOR ROOF CONSTRUCTIONS

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Abstract
This research was carried out to start the discussion on the amount of harmful emissions that are emitted in producing building and insulation materials for roof constructions. Usually, for the improvement of energy efficiency of buildings and reduction of the embodied thermal energy, effective thermal insulation solutions for the external building envelope have to be provided. From the buildings available for the analysis, in Latvia there were selected multi-apartment buildings of separate series with a uniform composition of roof constructions. Within the context of renovation works, the reports of energy audit for the buildings contain recommendations referred to improvement of the thermal performance of roofs. Using mutually comparable energy efficiency report data, there was drawn up an averaged model of a five-storey multi-apartment residential house. There were taken into account legislative documents relating to thermal engineering of buildings: LBN 002-01 'Heat engineering of building boundary constructions' and LVS EN ISO 6946: 2007 'Building components and building elements – Thermal resistance and thermal transmittance', and moisture regime according to LVS EN ISO 13788: 2001 'Hygrothermal performance of building components and building elements – internal surface temperature to avoid critical surface humidity and intersatial condensation – calculation methods', which states that the roof constructions should be free from possibility of water vapor condensation. In this study, there were calculated energy savings obtained by improving thermal resistance of the roof constructions and the opposite primary energy consumption for the production of building materials. As a result, there is obtained environmentally friendly roof construction.
Key words: insulation materials, primary energy, energy efficiency, roof constructions.

Introduction

When increasing thickness of the existing thermal insulation layer in buildings under renovation or providing additional insulation of new buildings, there is projected the expected thermal energy savings expressed in megawatt hours. The saved megawatt hours are equivalently expressed in CO_2 emission savings, the amount of which depends on the type of the fuel.

To produce thermal energy for heating, usually in conjunction with CO_2 emissions, the atmosphere is polluted with acid creating NO_X, SO_2, OH^- chemical compounds, which are recognized as causes of acid rains. The primary air pollution, caused by the production of thermal energy, is expressed in CO_2 emissions as this is an indicative figure – the smaller amount of CO_2 emissions is discharged into the atmosphere, the smaller is presence of other harmful chemical elements in flue gasses of the boiler house (Woolley, 2005).

The total CO_2 emission savings per year, resulting from reduction of the embodied thermal energy and CO_2 emissions which in their turn result from production of materials for construction of buildings, must be positive. By improving the energy efficiency of buildings, there are projected cash savings on the account of thermal energy savings but in the list of measures improving energy efficiency of buildings, there is included thicker thermal insulation levels, for the production of which enormous amounts of energy are spent in plants.

Embodied energy or primary energy (GJ m^{-3}) is the term used to describe the total amount of energy used in the raw materials and manufacture of a given quantity of product. For products specially made for their insulating properties, it is true that all will probably save many times more energy during their life than is consumed in their production. Most will achieve energy break – even in months or years when compared to uninsulated structure. For a building to be green it is essential for the environmental impact of all its constituent parts and design decisions to be evaluated. This is a much more thorough exercise than simply adding a few green elements such as grass roof or a solar panel. The purpose of the digest is to help designers, specifiers and the clients to make relatively objective decisions about the environmental impact of materials, products and building solutions with some reasonably hard facts, at least as far as the current state of the art (or science) permits (Woolley, 2005).

The aim of research was to develop an alternative roof construction made from nature friendly materials and low primary energy use for production of insulation materials to reduce outflow CO_2 and other amount of acid compounds in atmosphere. For theoretical research, energy efficiency rating data was collected from eight energy audit reports made in heating season of year 2010 to 2011 (Table 1).

Table 1

The data of energy audits for five-storey buildings through additional insulation of the roof construction

Address	Series	Heated area, m^2	Initial rating of energy efficiency, kWh m^{-2} per year	Savings, kWh m^{-2} per year
Jelgava, Asteru 6	103	3,958.7	163.0	13.3
Jelgava, Pasta 55	103	1,358.1	150.4	13.8
Jelgava, Pulkveža O.Kalpaka 35A	103	4,120.3	170.9	12.8
Salacgrīva, Pērnavas 10	103	3,188.8	154.5	15.9
Jelgava, Lielā 32	316	2,233.0	134.6	14.1
Jelgava, Lielā 34	316	2,184.5	167.5	15.1
Jelgava, Raiņa 9	318	2,541.2	153.5	13.3
Jelgava, Uzvaras 2	318	2,318.4	137.1	13.3
Average:		**2,737.9**	**153.9**	**14.0**

Materials and Methods

In order to carry out research on the embodied energy for production of materials for roof structures and analyze moisture processes, there was adopted a concept consisting of six parts:

a) identification of the combined roof structure for the existing buildings;
b) energy audit data collection, which lists improvement measures for roof constructions in the same conditions;
c) recording of the required energy consumption for materials listed in the improvement activities;
d) comparison of the thermal energy savings with the amount of energy required for the production of building materials;
e) useable renewable resources;
f) analysis of moisture processes in the event of an existing and alternative structure.

For the analysis of the roof structures, there was chosen a standard covering for the top floor of buildings, which consist of light concrete and brick walls with hollow covering panels for floor and flat roof constructions (typical for 103rd, 316th and 318th series of multi-apartment buildings in Latvia). We paid attention to these series of buildings as the development dynamics of energy efficiency improvement measures for multi-apartment buildings in Latvia is currently in an early stage. The structure of the combined roof constructions (Fig. 1) is the same in all of these serial buildings. For calculated in energy audits and included in this research five-storey buildings with combined roof constructions, the thermal transmittance values (U) were as follows: calculated before renovation U = 1.016 to 1.020 W m^{-2} K^{-1}, after renovation projected U = 0.201 to 0.207 W m^{-2} K^{-1} (LVS EN ISO 6946). Normative U value is 0.211 W m^{-2} K^{-1} (LBN 002-01). The heating areas of five-storey buildings range from 1,358.1 to 3,958.7 m^2, the original energy efficiency assessment is measured from 134.6 to 170.9 kWh m^{-2} per year.

The analysis of energy audit data was carried out for five-storey buildings (Table 1). In all the research pertinent energy audits there is recommended an additional thermal insulation of the roof construction with a 16-cm-thick thermal insulation layer, resulting in the projected savings within the limits from 12.8 to 15.9 kWh m^{-2} per year. For complementing the roof structure of the existing buildings (Fig. 1), rock wool panels in two layers, 12 cm and 4 cm in thickness, were recommended for the thermal insulation.

According to the data in Table 1, for a standard five-storey building with a combined roof construction, the heated area is 2,737.9 m^2, the measured energy efficiency rating before the improvement measures is 153.9 kWh m^{-2} per year, and the projected savings through the additional thermal insulation of the roof construction with solid rock wool insulation of 16 cm in thickness – 14.0 kWh m^{-2} per year. In this case, the roof area may be taken equal to the area of one floor, i.e., dividing the heated area by five, there was obtained the roof area of 548 m^2.

Table 2

The embodied energy for the production of heat insulating materials (Woolley, 2005)

Material	Embodied energy (GJ m^{-3})
Plastic insulation (EPS, XPS)	4.05
Foamed glass	2.70
Mineral wool	0.83
Cellulose fiber	0.48
Sheep's wool	0.11

For the purpose of taking measures for improving the building envelopes, thermal insulation materials are needed, in addition, each of them has a different amount of the embodied energy (Table 2; Woolley, 2005).

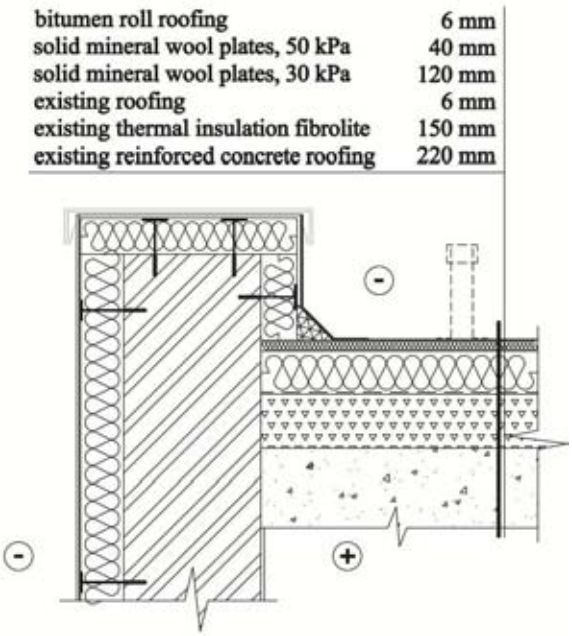

Figure 1. The structure of the roof construction for the existing building projected in the energy audit.

Results and Discussion

The thermal energy savings per year, when insulating the roof construction with the average area of 548 m^2, the average heated area amounts to 2,737.9 m^2 and the savings – 14.0 kWh m^{-2} per year for each square meter of the heated building, resulting in the calculated 38,330 kWh or 38.33 MWh per year.

For the production of one square meter of the mineral wool insulation 16 cm in thickness, according to the data of Table 2, the required energy amounts to 0.133 GJ m^{-2}. Together over the entire roof area calculated above, for the production of the thermal insulation materials, the embodied energy amounts to 72.88 GJ. Knowing that one joule is one watt per second, it is calculated that over the entire roof area, the embodied energy amounts to 20,250 kWh or 20.25 MWh. It is important to note that in the process of producing the mineral wool, in addition to the CO_2 pollution, there occurs emission of NO_X, SO_2, OH^- chemical compounds generating acid rains. The tiny mineral wool dust settles down in the human respiratory tract and irritates the skin (Woolley, 2005).

In the light of the results of calculations, when performing the thermal insulation works in the rock wool thermal insulation materials, the amount of energy embodied in the production of materials, in nature disperses in around 6.4 months. This means that when thermally insulating roof constructions, the total thermal energy savings per year are greater than the amount of the embodied energy in the production of building materials. It should be noted that the planned CO_2 emission reductions in the air through the roof thermal insulation of the existing buildings with mineral wool, in fact, will be on 53% lower.

If the rock wool insulation is replaced by cellulose fiber insulation in a wooden frame (Fig. 2), the required thickness of the insulation layer is 18 cm and for the production of such composite structures, the required energy amounts to 18,040 kWh or 18.04 MWh. For the production of timber, the adopted primary energy amounts to 0.26 GJ m^{-3} (Sustainable homes…, 2010).

Fig. 2 presents the (2nd version) roof construction with the calculated heat transfer coefficient U = 0.204 W m^{-2} K^{-1}, additionally calculating the ventilated layer of air and moisture resistant plywood U = 0196 W m^{-2} K^{-1}. The amount of the embodied energy for the production of the 2nd type of the roof construction materials, in nature disperses in around 5.7 months. The cellulose fibers and timber production do not contribute to emission of chemical compounds, which are considered to be the causes of acid rains.

For the roof structure solution with the cellulose fiber insulation, calculation was done following the standard LVS EN ISO 13788: 2001, according to which there is formed a non-essential vapor condensation possibility in the construction. This calculation did not take into account the air exchange of the ventilated layer and output effects of aeration, which convincingly provides a construction free of possibility to form a steam condensate. In turn, in the renovated roofs where for the improvement there is not dismantled the existing waterproofing layer, in parallel constructing a new waterproofing on the outside, a combined water vapor condensation and evaporation processes with a positive overall annual balance take place. This means that, so far, for standard renovated roofs under the influence of insufficient ventilation of the internal layers there can arise serious problems with the accumulated steam condensate (Krēsliņš and Borodiņecs, 2007).

In the 1st and the 2nd version, the roof constructions are considered to be alike in terms of construction costs as the cellulose fiber insulation is cheaper than the rock wool plates, so the woodwork in the 2nd version of the construction does not raise the cost of the total solution.

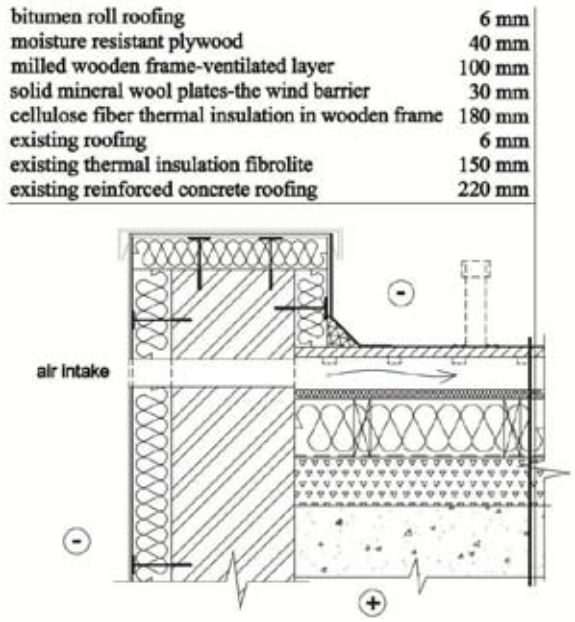

Figure 2. An alternative solution of the roof construction of the existing building with a cellulose fiber thermal insulation (concept based on Фокин, 1973).

Conclusions

In order to have a positive balance of CO_2 reduction, for each roof construction of thermally insulated multi-apartment building, it is allowed to produce on 1.8 times more insulation material of rock wool (2.1 times in the event of the cellulose fibers).

There was obtained coherence with the number of the thermally insulated buildings and the allowed number for the next year, which is approximately twice the amount, provided that CO_2 emissions will not be reduced but the balance of the chemical substances NO_X, SO_2, OH^- generating acid rains in the atmosphere will be increased.

Within the roof renovation measures of having the rock wool insulation, the actual CO_2 emission reduction amounts to 47% of the projected one, and respectively 53% if there is used the cellulose fiber insulation in a wooden frame.

The roof construction with a ventilated layer is safe from the possibility of water vapor condensation, but with horizontal roofs without air movement and adequate aeration solutions there is high probability for a lasting vapor condensation.

References

1. Krēsliņš A., Borodiņecs A. (2007) Analysis of condensation risk in wooden framework constructions. *The 12th Symposium for Building Physics*, Dresden, Germany, pp. 847–851.
2. LVS EN ISO 13788: 2001 Hygrothermal performance of building components and building elements – internal surface temperature to avoid critical surface humidity and intersatial condensation – calculation methods (2001) VSIA Latvijas Standarts, Rīga, 36 p.
3. LVS EN ISO 6946: 2007 Building components and building elements – Thermal resistance and thermal transmittance (2007) VSIA Latvijas Standarts, Rīga, 35 p.
4. Regulations issued by the Cabinet No.495, LBN 002-01 Heat engineering of building boundary constructions. November 27, (2001) Available at: http://www.likumi.lv/doc.php?id=56049, 15 March 2012 (in Latvian).
5. Sustainable homes: embodied energy in residential property development. Hastoe Housing Association (2010) A Guide for Registered Social Landlords. Available at: http://www.sustainablehomes.co.uk/upload/publication/Embodied%20Energy.pdf , 15 March 2012.
6. Woolley T. (2005) *Green building handbook: a guide to building products and their impact on the environment*, Taylor & Francis, London, UK, 216 p.
7. Фокин К.Ф. (1973) *Строительная теплотехника ограждающих частей зданий (Constructional thermal engineering of building envelopes)*, Стройиздат, Москва, 289 с. (in Russian).

REGULATED STREAMS REHABILITATION USING BIOENGINEERING METHODS

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Abstract
Within several decades many natural Lithuanian rivers were straightened and adapted for needs of soil drainage. By 1998, 63.4 thousands kilometres of trenches of which approximately 46 thousands kilometres were regulated rivers and streams were excavated. It is calculated that trenches of regulated rivers and streams currently cover 82.6, and natural – only 17.4% of total rivers network. While straightening rivers, their channels were extended, their slopes were changed, and bends were removed. Thus, it ensured a fast removal of excess water from drained areas of ground. However, as in the straightened rivers an equal stream was present, unfavourable conditions arouse for ichthyofauna, as well as for settlement and evolution of the invertebrates. Furthermore, possibilities for self-purification of water running through the channel were reduced. In order to restore morphological, hydraulic, and especially ecological conditions, close to natural ones, of the straightened rivers, it is necessary to renaturalize them. The analysis of river naturalization and renaturalization ways and means was performed on the basis of the reviewed projects carried out in foreign countries. Four renaturalization methods were identified: self-naturalization, soft naturalization, partial and full renaturalisation. The possibility to use these naturalization methods were evaluated taking into account environmental conditions of Lithuania. The analysis of naturalization projects implementation showed that the best way to rehabilitate Lithuania's straightened rivers is to use partial renaturalization method that lets form more favourable ecological environment of rivers. The object of the research was - to evaluate the most suitable naturalization methods for Lithuanian conditions.
Key words: regulated streams, channel bends, vegetation, renaturalization.

Introduction

During the period of 1961-1990 in Lithuania more than 3.0 million ha were drained with the help of drains. During independence period, starting in 1991, the volume of installation of new drainage systems and renovation works gradually reduced. In 2001, 5 ha were drained and renovated 1320 ha; meanwhile, in 2010 only 866 ha were renovated (Šaulys and Guklys, 2011).

Majority of regulated rivers were managed consistently, by trying to ensure their exploitation properties and functionality of melioration systems (Vilkevičiūtė, 2003). However, as the age of drainage systems increases, deterioration of melioration building increases as well. Drainage systems, older than 40 years, take over 45% (Maziliauskas et al., 2007). Funding of exploitation of drainage systems since 1998 until 2002 reduced 2.6 times (from 74 millions Lt to 26.7 millions Lt), and the area of faulty, badly functioning drainage systems increased in 1.7 times (from 163 to 27.5 thousands ha) (Buožis, 2003). According to the data received in 2010, total deterioration of melioration buildings reached 55.7%, buildings of drainage systems – 50.7%, and arterial leading network - even 70.6%. Analysis of technical status of drainage systems and variation of possibility of drainage faults in regions allows prognosticating that faults of drainage systems are going to increase in the future, for this reason drainage systems, which are not effectively used in agricultural production should be naturalized (Šaulys and Gurklys, 2011).

There are 4 possible ways for naturalization of Lithuanian regulated rivers network: self-naturalization, mild naturalization, partial renaturalization by using engineering means, and renaturalization, by reforming river channel completely. According to evaluation of economy and environment protection, it was identified that the most optimal way is partial rehabilitation of channels by using bioengineering methods: plants, comfreys, stones, brushwood, logs, stumps, gabions and other. When using these means in the regulated channel, conditions necessary for the development of natural variety form.

Having summarized methods and means of naturalization, packets of bioengineering methods, which may be applied for rehabilitation of Lithuanian regulated streams, under different natural conditions are introduced. The object of the research is to evaluate the most suitable naturalization methods for Lithuanian conditions.

Materials and Methods

In order to evaluate the impact of river' straightening on Lithuanian rivers, first, literature on characteristics of natural and regulated rivers and their impact on hydrographical network, on morphological and hydrological parameters of regulated rivers (Dumbrauskas et al., 1998; Freshwater..., 2001; Gailiušis and Kriaučiūnienė, 2001; Habitat..., 2004; Kutra et al., 2006; Lamsodis, 2001; Vaikasas, 2007) was reviewed. According to the reviewed

experience of foreign countries, ways and methods of rehabilitation of regulated rivers are analysed and summarized (Conservation…, 2007; Danish…, 1995; Florineth, 2008; Freshwater..., 2001; Jormola, 2006, 2008; Living…, 2006; Longinojan…, 2006; River..., 1996; The river …, 1998). Natural means of naturalization are being reviewed and grouped according to origin and possibilities of use (Chanson, 2000; Christensen 2000; Cokgor, 2004; Danish, 1995; Fischer and Fischenich 2000; Florineth, 2008).

Having summarized material gathered in literature, 5 groups of rehabilitation by bioengineering methods have been highlighted. These groups are composed according to slope (<0.7 m km^{-1} and >0.7 m km^{-1}) and natural environment (field, forest, field-forest) for which are suggested bioengineering packets. Finally, an example for partial naturalization method for regulated rivers is proposed.

Results and Discussion

Consequences of rivers regulation

Melioration basically changed the environment, hydrography, morphology and hydrology of rivers and streams. It gave a new meaning to engineering building with the purpose of accumulating and freeing water in time from the drained areas (Lamsodis, 2001). When performing melioration works, bands of forests and scrublands, through which migrated animals were destroyed. After having drained some swamps, the regime of ground water changed, processes of bend formation stopped, wind erosion increased, but the level of ground water decreased (Vilkevičiūtė, 2003).

Drainage of grounds has changed network of Lithuanian rivers and streams as well as processes occurring in their channels. Morphological, hydrological, and hydromorphological changes of hydrographical network in channels of regulated streams and influence of those changes on flora and fauna are being introduced.

Changes of hydrographic network. Channels of rivers and streams of intensive ground drainage to the extent of all country shortened for 2.5 km or 8.2% on average, and areas of river-basins changed correspondingly – 7.5 km^2 (12%) (Gailiušis and Kriaučiūnienė, 2001). It is calculated that after having drained 46.6% of country territory, the length of river channels increased from the mentioned above 63.4 thousand km to 76.8 thousand km, i.e. approximately 20.6%, and the number of rivers reduced from 29.1 thousand to 22.2 thousand, i.e. 23.7% (Gailiušis and Kriaučiūnienė, 2001).

Morphological changes. After having straightened the streamways, their morphology has changed: limits and the shape of the streamway, structure of slopes, shape of coastline, substrate of the bottom, also hydraulic conditions of the current have changed. After having straightened streamways, it obtained a shape of regular trapeze in leading trenches. After having straightened streamways, their longitudinal slopes have increased even up to 1.5–2.0 times, and simultaneously water speed and outwash discharge have changed. In the upper reaches of the straightened rivers and streams due to high speed of the current, as washing force of water increased, intensive erosion processes, which influence widening and sinking of streamways occur. Meanwhile, in the lower reaches of the straightened rivers and streams, the streamway silts up, due to the satiation of current with the outwash (Vaikasas, 2007). Thus, in the straightened streams and rivers with a monotonous, fast current and with the silted streamway bad conditions for settlement and living of fishes and other ichthyofauna form.

Hydrological changes: After having straightened the rivers, their hydrological parameters – the speed of the current, debit, module of run-off, and slope have changed. Since the module of run-off best evaluates changes of hydrological regime, for this reason changes of natural hydrological regime of rivers have been evaluated according to the changes of quantity of natural yearly run-off. As the run-off has changed, i.e. water quantity in the river-basin, river discharges have changed as well. According to the researches of A. Dumbrauskas, A. Povilaitis and others (Dumbrauskas et al., 1998; Kutra et al., 2006), changes of the run-off are related with intensified after rivers' straightening, land usage and with changes of water balance. It is identified that the impact of stream straightening on decrease of run-off may be not more than 2-3%. Greater influence on discharge of the straightened river is felt in a small river-basin, but in bigger rivers only deviant balance of surface - ground discharge is felt more.

Hydromorphological conditions strongly influence the change of physical - chemical parameters of the streamway. After having straightened the rivers, a water current starts running faster in the streamway, while the possibility of water self-depuration decreases. As nourishment accumulates, favourable conditions for water plants development appear. In water, saturated with nourishment, the usage of oxygen consumption which is harmful for water animals increases. Thus, as values of physical - chemical parameters change, conditions of water animals' existence in basin change as well.

Impact on flora and fauna. During the period of straightening of rivers and streams, water and riverside fauna and ichthyofauna which until that moment was present was destroyed. Its rehabilitation was blocked by later performed works of maintenance of drainage systems (Freshwater..., 2001). After having straightened the streams, shrubbery and trees have been cut, grass flora has changed them. Haymaking of

streamway slopes and cleaning of the bottom did not allow rehabilitation of prior water flora. As the flora has changed, inhabitation has changed as well, and this has influenced changes of ichthyofauna. When straightening rivers and streams, stones, remains of tumbled trees, water plants, which are very important for reproduction and living conditions of ichthyofauna have been removed from their streamways. It is possible that straightening of rivers and streams, which influenced destruction of inhabitations, encouraged extinction or reduction of some types of water animals (Habitat..., 2004).

Rehabilitation methods of the regulated rivers

In order to restore morphological and hydrological parameters of the regulated rivers, and improve ecological condition, naturalization or renaturalization of streams is being used in the world. Many sources of literature a conception of naturalization and renaturalization name quite similarly. In Lithuania, in technical regulation of melioration it is indicated that naturalization or self-naturalization takes place when trenches or other artificial objects are overgrown with vegetation, and when the profile of trench streamway is naturally formed. Meanwhile, by artificially allowing naturalization of stream or by other means, which are artificial for humans, restoring natural balance, this process may be called artificial naturalization or *renaturalization*. According to technical regulation of melioration, renaturalization – is rehabilitation of original natural condition of trenches or land areas in artificial way. Thus, when human beings contribute to rehabilitation of natural processes or to other acceleration, the so-called renaturalization process takes place.

On the basis of scientific (Danish…, 1995; Jormola, 2006; Florineth, 2008; River..., 1996) researches and experience of other countries, it was recommended that the straightened streams were naturalized/renaturalized only in compliance with certain methods. When describing conceptions of naturalization and renaturalization in a wider sense, it is possible to equate them with natural and artificial ways of river rehabilitation.

Figure 1. Streamway self-formation of Šventutė stream. (aut. R.Baublys).

A self-naturalization - growing of shrubbery and trees on the slopes of streams, when human beings do not control this process is the simplest way of rehabilitation of the straightened streams (Figure 1). Bigger plants overrun smaller ones at the base of the slope, and thus keep the streamway clean. Small trees and shrubbery which grow on the slope, with their roots reinforce slopes of the stream, thus, not allowing deformation of slopes and their bases. The streamway forms self-basis, shrubbery and trees growing on the slope limit meandering of streamway and stop erosive impact of the current. In the straightened streams a natural dynamic balance among impact of the current and stability of the streamway happens during a long period of time. Then deformations (washing, choking) of the streamway are slow, or they do not occur at all. While naturalizing the polluted streams, this balance gradually returns (Tumas, 1997). Thus, by not correcting processes occurring in the streamway, natural balance in the stream forms naturally. It does not cost anything, though this process may take hundreds of years. However, roots of shrubbery and trees growing on the slopes may plug drainage mouth, and grass and shrubbery with big stems, which grow on the slopes, may easily spread to nearby farmlands and grasslands. Method of self-naturalization may be used in all areas which are drained by the drainage, by appropriately applying drainage systems.

Figure 2. Kocksbybacken (Jormola, 2006).

Recently more and more often the term *mild naturalization* is being used (Freshwater..., 2001). In this case it is allowed to occur for natural processes in the streamways, though this whole process is being supervised and adjusted by human beings (Figure 2). When using this method of naturalization, cleaning of streamways stretches and removal of plants is performed by manual work. It is allowed for one slope being overgrown with forest plants, whereas from the opposite slope plants are being removed in

order to allow the required permeability and facilitate works of maintenance and cleaning. With the help of this method rehabilitation of meandering of the straightened streams is possible, by using both energy of the current, and plants, growing on the slopes.

By using this method large plants which grow on the slopes overgrow smaller plants. Thus, the streamway remains clean and better permeability of the streamway is reached. A streamway starts self-formation, human beings only have to observe that significant deformations would not occur. In such a way the volume of maintenance works is reduced. However, by using this method a danger for drainage mouth occurs, because it may be plugged by roots of trees and shrubbery. For this reason in such stretches it is necessary to change drainage mouths to non-perforated plastic pipes. This method may be widely used under Lithuanian conditions, because this does not require huge investments, and only constant supervision of the straightened streams is needed.

Meanwhile, renaturalization – an artificial rehabilitation of the straightened streams which are close to conditions of natural environment is applied. In this case morphological properties which are close to natural ones are being created artificially: bends are formed and banks are reinforced by natural and artificial means. Thus, favourable conditions for settlement of animals and plants, returning to streamways in the most possible natural condition are created. Two methods of artificial rehabilitation (renaturalization) of streamways of the straightened rivers are distinguished, i.e. partial and full rehabilitation of streamway.

Figure 3. Longinoja stream (Jormola, 2006).

Partial rehabilitation of streamway is a rehabilitation of streamway, by using bioengineering methods and energy of the current (Figure 3). When using the method of partial rehabilitation of streamway, the streamway is being restored by using various bioengineering methods, - wicker fences, stones, fascines and other. By using bioengineering methods in the regulated streamway, conditions necessary for development of natural variety are formed. With a help of this method human beings allow closer direction formation of the streamway under natural conditions. When using this method, the target goals are faster achieved, compared to the use of aforementioned methods. However, the use of this method requires investments, i.e. much assets and work costs demanding method. This method is broadly used in Western European countries; thus by using experience of other countries, this method of renaturalization may be used in Lithuania in full.

Figure 4. River Skerne, (River..., 1998).

Full rehabilitation of streamway is a method when bends, coves and elements of natural streamway, necessary for increase of natural variety (Figure 4) are formed by artificial means. Full rehabilitation of the streamway is performed by fully reforming streamway, when bends, coves are established by using the aforementioned bioengineering methods. A newly formed streamway with bends, coves and islands establishes especially favourable conditions for development of water plants and animals. These conditions are very close to the natural condition of the river before its straightening. This is one of the most effective means of achieving the desired goals faster. As hydrological and hydraulic conditions have changed in the artificially formed habitats, both animals and plants settle in quite soon.

The recent method is quite expensive, demanding much assets and high work costs, though currently it has gained popularity in projects of river rehabilitation in various countries of the world: Australia, the USA, Great Britain, Netherlands, Finland as well as in other countries (Conservation…, 2007; Jormola, 2006, 2008; Living…, 2006; Longinojan…,

2006; The river …, 1998). It is noticeable that this method is more efficient, and its results are seen quite early.

Figure 5. Detached stones arranged in the streamway. (BEF…).

Means of restoration of the regulated rivers

The main goal of means of rehabilitation of streamways is to restore natural processes in the streamway, thus creating biological variety in streamways and in the zones of riversides and stabilized regime of outwash. Artificially formed constructions would influence changes of morphological and hydrological characteristics of the current and allow formation of river conditions, which were close to natural ones. In projects of river rehabilitation, various bioengineering means: grass and ligneous plants, detached stones, stone casts, stone thresholds, logs, fascines, tumbled trees, stumps are applied.

Grass and ligneous plants. Stretch of ligneous plants next to the streams is an effective filter of biogenic materials (Fischer and Fischenich, 2000; Christensen, 2000). Dense riverside vegetation forms a more favourable space for formation of habitats and makes a shadow for a streamway, thus decreasing temperature of river water. Consequently, in cooler water saturation of oxygen increases (Cokgor, 2004; Chanson, 2000). Grass and ligneous plants, which grow on the streamway or in the zone of water level fluctuation create favourable conditions for slowing of the current, and subsequently for accumulation of outwash, which indirectly influences formation of shoals, swims, and bends.

Stones. These means may be easily used in the current of various slopes and speeds. What is more, they are more resistant to more intense influence and they are long-lived (Figure 5). Detached bigger stones thrown in the streamway along the riverside form a larger variety of conditions in the streamway. As morphology of the streamway changes, shoals, swims, which later contribute to formation of bends, by thus forming a variety in the streamway, encouraging reproduction and migration of fishes are formed. Stone casts form a current allowing to change the river current from the eroding bank towards the opposite bank. With their help in the regulated streamway bends may be formed. These constructions are applied for rehabilitation of inhabitations, together with increasing of fish quantity and variety (Danish, 1995). Stone casts and stone thresholds form conditions for mixing of the current; thus, it helps to perform the saturation of the current with oxygen (Chanson, 2000).

Figure 6. Use of logs when forming river bends. (Florineth, 2008).

Tree constructions, used in projects of rivers renaturalization, consist of logs, fascines, branches, tumbled trees, stumps, which are arranged in the streamway (Figure 6). These are the most often used means in projects of river rehabilitation. Their use is possible under various conditions, under morphometric conditions of the regulated river. These means are used as current deviating, pressing means; thresholds are formed with their help. Also, these means are used in order to naturally form bends of the streamway and in order to secure riversides from erosive impact of the current. As silt accumulates behind tree construction, forming solid structure of plants, it then forms habitats for riverside and water animals. As silt accumulates and vegetation settles in, a shadow is formed that decreases water temperature, and more intensive current, next to the settled fascines, creates conditions for better saturation of oxygen.

Summary of Results and Suggestions

After having summarized the methods of rehabilitation of the regulated rivers, it is possible to state that the most suitable river renaturalization under Lithuanian conditions is partial. It is influenced by larger efficiency of self-naturalization and mild

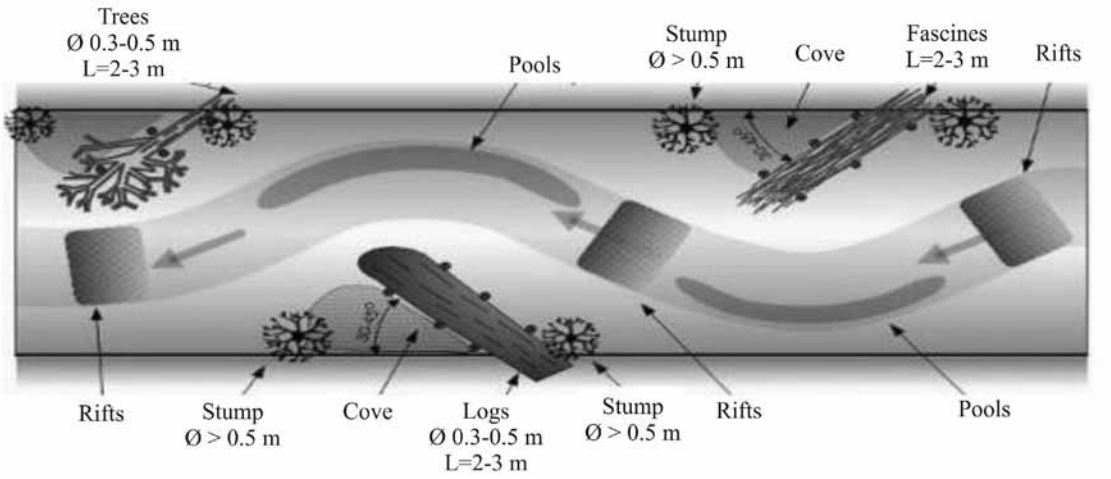

Figure 7. Use of renaturalization means in the range of regulated river Apaščia from the second group. (aut. R.Baublys).

renaturalization by using this method. Also, it is a more economical method of rehabilitation in comparison with full renaturalization method.

Having reviewed and evaluated possible bioengineering methods that are suitable to natural environment of Lithuania, it is suggested that all above discussed means could be used in Lithuania when restoring the regulated rivers.

In order to restore ecological balance in the regulated rivers and streams, it is essential to consider that each regulated stretch differs in the basin width, slope and natural environment (forest, outskirts and field). According to these criteria, 5 groups of the regulated rivers are distinguished. Packets of means are formed for each group of rivers rehabilitation.

Small streams (<100 km^2) are included in the first group. Their ecological efficiency of self-rehabilitation is considerably small. For this reason streams of this group are not analyzed. They are left for self-naturalization, and engineering means for their rehabilitation are not used.

The second group encompasses streamways, regulated in forest, with a slope smaller than 0.7 m km^{-1} and the area of the basin bigger than 100 km^2. For this group natural means close to the forest environment are suggested to be used: logs, fascines, tumbled trees, stumps.

To the third group belong streams which run in fields, with the slope smaller than 0.7 m km^{-1}, and the area of the basin bigger than 100 km^2. For this group logs, fascines, stone casts, detached stones are suggested to be used.

To the fourth group belong streams, with a slope smaller than 0.7 m km^{-1}, running in outskirts (width of the basin is bigger than 100 km^2). For this group both field and forest materials: logs, fascines, tumbled trees, stumps, detached stones may be used.

The fifth group includes the regulated streams, which run in fields, though their slope is bigger than 0.7 m km^{-1} (width of the basin is bigger than 100 km^2). For these streams alongside with standard means of naturalization (logs, fascines) means that are more resistant to the impact of current: stone casts, thresholds of stones and logs, big detached stones are suggested to be used.

For each aforementioned group, by using bioengineering methods, possible variants of use of means are formed. According to the available materials and regularities of streamway formation, a possible presentation of example of partial method of rivers renaturalization use is shown (Figure 7).

Means of river rehabilitation are used according to the regularities of natural meandering. It is stated that the length of natural bends depends on the width of the streamway and is expressed in the following correlation: L = (10-14) B (Danish, 1995; Vaikasas, 1999, 2000). In order to form a bend, two means which form the streamway are necessary (e.g. logs, fascines and other). They are formed on different sides of the streamway, at every half of the length of the bend. At such a distance, on different riversides of the streamway, various streamway forming means: tumbled trees, logs, fascines, stone casts and other are arranged.

Measurements of used means depend on the speed of the river current, on the depth and width of the streamway, and on particular conditions of location and construction. General requirements would be that these means were not longer than 1/3-1/2 width of the stream way. The size of the means is calculated according to the parameters of the streamway. By arranging the aforementioned elements on different riversides of the streamway, conditions for self-current, using self-energy to form the streamway by

morphological, hydrological and ecological variety which is close to natural are created.

Similar arrangement of means is possible in all renaturalization groups of rivers. For a specific group means and their usage on different parameters of the rehabilitated river differ.

Conclusions

1. Having reviewed the naturalization methods used in foreign practice, it is suggested to use partial renaturalization method for rehabilitation of Lithuanian regulated rivers.
2. Bioengineering methods are most suitable for implementation of renaturalization projects due to their ecology and naturalness for natural environment.
3. According to the slope and natural environment, 5 groups of regulated rivers are distinguished.
4. For each distinguished group of regulated rivers the method of rehabilitation and packet of rehabilitation means is attributed. For the first group it is suggested that self-naturalization is used, for the second, third, fourth and fifth – the method of partial renaturalization should be applied.

References

1. BEF‘s work with water - A Central Oregon travel log (2010) Watershed restoration. Available at: http://www.b-e-f.org/blog/2010/08/17/bef%E2%80%99s-work-with-water-%E2%80%93-a-central-oregon-travel-log/, 12 February 2012.
2. Buožis V. (2003) Drenažo remonto ekonominio efektyvumo tyrimai (The investigation of drainage maintenance economical efficiency). *Water Management Engineering*, 23(43)-24(44), pp. 132–137. (in Lithuanian).
3. Chanson H. (2000) *The Hydraulics of Open Channel Flow*. Oxford, Auckland, Boston, Johannesburg, Melbourne, New Delhi, p. 579.
4. Christensen D. (2000) Protection of riparian ecosystems: a review of the best available science. Jefferson County Natural Resources Division. Port Townsend, WA. p. 4.
5. Cokgor S., Kucukali S., Diplas P. (2003) Oxygen transfer around boulders. Proc., XXX IAHR Congress conference 24-29 August, Thessaloniki, Greece, pp. 219–226.
6. Conservation of wetlands in Ķemeri National Park, Latvia (2002) Project: LIFE2002/NAT/LV/8496. 2007; p. 25.
7. *Danish watercourses: Ten years with the new watercourses act.* (1995) Ministry of Environment and Energy. Miljonyt, Denmark, p. 208.
8. Dumbrauskas A., Iritz L., Larsson R., Povilaitis A. (1998) *Environmental Effects of Agriculture Practices. Hydrology and Nutrient Transport*. Part I - Water Cycle. Report No 3218, Lund, Sweden, p. 62.
9. Fischer R.A., Fischenich J.C. (2000) Design recommendations for riparian corridors and vegetated buffer strips. Technical Note ERDC-TN-EMRRP-SR-24, Army Engineer Waterways Experiment Station, Vicksburg, MS. p. 17.
10. Florineth F. (2008) *Monitoring von revitalisierten Teilstrecken des Mödlingbaches im Stadtgebiet von Mödling*. (Monitoring of Revitalized Sections of the Mödling Creek in the City of Mödling). Vienna, 105. S. (in German).
11. *Freshwater ecosystems* (2001) Biodiversity management issues 8. Department of Natural Resources and Environment (NRE), Australia, p. 4.
12. Gailiušis B., Kriaučiūnienė J. (2001) Ūkinės veiklos poveikio vertinimas vandens telkinių hidrologiniam režimui (The Impact Assessment Economic Activity for Water Bodies Hydrological Regime). *Lietuvos energetikos instituto konferencijos darbai 2000*. LEI Kaunas, pp. 65–80. (in Lithuanian).
13. *Habitat Restoration Plan for the Middle Rio Grande*. (2004) Tetra Tech EM Inc., p. 145.
14. Jormola J. (2006) Current activities of Europe’s information exchange network and river policies. Slide presentation. ECRR/Finnish Environment Institute SYKE, Finland; p. 6.
15. Jormola J., Laitinen L., Sarvilinna A. (2008) Environmentally friendly drainage practices. Finnish Environment Institute SYKE. 10th International Drainage Workshop. Helsinki, Finland/Talin, Estonia. Slides presentation. Available at: http://www.fincid.fi/idw2008/pdf/04_jormola.pdf, 15 January 2012.
16. Kutra G., Gaigalis K., Šmitienė A. (2006) Land use influence on nitrogen leaching and options for pollution mitigation. *Agriculture*, vol. 93, No. 4, pp. 119–129.
17. Lamsodis R. (2001) Apie prielaidas melioracijos griovių gamtinėms funkcijoms plėtoti (Assumptions about the functions of natural drainage channels to develop). *Researches of Lithuanian university of Agriculture and Water management Institution*, 16(38), pp. 61-67. (in Lithuanian).

18. Living river Liesing. Demonstrative Ecological Reconstruction of a Heavily Modified Waterbody in an Urban Environment. Presentation. Water for life – Life for water, Brussels (2009) Available at: http://ec.europa.eu/environment/life/news/events/events2009/waterconference/documents/hydro_lirili.pdf, 19 January 2012.
19. Longinojan kunnostushanke (Long ditch rehabilitation project) (2006) Presentation. Filand, Helsinki, p. 28. (in Finnish).
20. Maziliauskas A., Morkūnas V., Rimkus Z., Šaulys V. (2007) Economic incentives in land reclamation sector in Lithuania. *Journal of Water and Land Development*, 11, pp. 17–30.
21. River Skerne. The river restoration centre. Brochure. UK (1998) Available at: http://www.therrc.co.uk/case_studies/skerne_brochure.pdf, 8 February 2012.
22. Šaulys V., Gurklys V. (2011) Sausinimo sistemų funkcijų atstatymo prioritetai (The priority of drainage system reconstruction feature). *Journal of water management engineering*, 38 (58), pp.14–21. (in Lithuanian).
23. The river Brede – enriching our countryside (1998) Committee for Technical and Environmental matters. Brochure. Denmark, p. 16.
24. Tumas R. (1997) Ūkininkavimas ir upių vandens kokybė (Farming and water quality). *Environmental engineering.* No. 25, 2(8), pp. 25–30. (in Lithuanian).
25. Vaikasas S. (1999) Reguliuotų upelių savaiminės natūralizacijos hidrauliniai klausimai (Hydraulic aspects of regulated channels naturalisation). *Lietuvos žemės ūkio universiteto ir Lietuvos vandens ūkio instituto mokslo darbai,* 7(29), pp. 31–40. (in Lithuanian).
26. Vaikasas S. (2000) Kanalizuotų upelių savaiminės natūralizacijos hidrauliniai klausimai (Hydraulic aspects of canalisated channels naturalisation). *Žemėtvarka ir melioracija*. No.1, pp. 46–53. (in Lithuanian).
27. Vaikasas S. (2007) *Ekologinė hidraulika (Ecological Hidraulics)*. Vilniaus Gedimino technikos universitetas. Hidraulikos katedra. Vilnius, Technika. p. 213. (in Lithuanian).
28. Vilkevičiūtė V. (2003) Hidrografinio tinklo pokyčiai dėl žemių sausinimo (Changes in hydrographical network due to land drainage). *Lietuvos Žemės Ūkio Universiteto Ir Lietuvos Žemės Ūkio Universiteto Vandens Ūkio Instituto Mokslo Darbai*. No. 22(44), pp. 136–140. (in Lithuanian).

ASSESSMENT OF BIOINDICATION METHODS IN AIR POLLUTION MONITORING

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Abstract
The aim of air pollution monitoring is a regular and continuous collection of information on air pollution to prevent hazards influencing ecosystem and its components, including humans. Nowadays, the main technology used for this purpose is electronic sensors. As they are designed for specific measurements, a lot of important factors cannot be evaluated – various pollutants diffusion or cumulative effect, exposure, dose, and bioaccumulation. As an alternative solution – bioindication – pollution level determination from its effect on certain indicator species can be used. So far potential usage of bioindication as current air pollution monitoring network's equivalent solution has not been studied. Therefore, the aim of the research was to assess a variety of bioindication methods for air pollution determination and their applications in air pollution monitoring. During the research, commonly used bioindication methods based on their popularity in scientific literature in 2012 were selected, as well as they were assessed using theoretical analysis method in order to determine their strong and weak points in air pollution monitoring. Research results demonstrate that current bioindication methods are not suitable for monitoring purposes. Therefore, bioindication can be combined with citizen science approach. To incorporate citizen science approach in bioindication based air pollution monitoring, development of special, for this purpose designed bioindication methodology is needed.
Key words: bioindication, air pollution monitoring, citizen science.

Introduction

The aim of air pollution monitoring is a regular and continuous collection of information on air pollution to prevent hazards influencing ecosystem and its components, including humans. For this purpose, air pollution monitoring programs are carried out. Obtained information goes to regulatory authorities, where it is used in decision-making process for pollution reduction activities and public awareness raising.

Information on air pollution can be obtained in two ways – by dispersion modeling (mathematical simulation of the spread of pollution from known emissions sources) and by direct measurement. Dispersion modeling has gained more popularity because it is cheaper. However, an effective air pollution monitoring without direct measurements is not possible, because direct measurements are more accurate and required for validation of dispersion models. For this purpose, automated measurement stations, equipped with various sensors, are placed in surveyed area (Conti and Cecchetti, 2001). This type of measurement has both its advantages and disadvantages. The situation in air pollution field is constantly evolving. Nowadays, diffusion of various pollution types becomes more important (Falla et al., 2000), for example, dust particles mixed with NOx. Such cumulative effects can cause greater impact on ecosystem and human health, as if the same pollutants interact separately. In addition, the cumulative effect is much more difficult to assess, especially using electronic sensors. Greater importance is given to weak and diffuse sources of emissions; thus, it is important to assess the pollution of not only close proximity to the largest known pollution sources (Hodin and Hertz, 1996) but also in the whole monitored area.

These problems demonstrate several drawbacks of current air pollution monitoring solutions. Since electronic sensors in measurement stations are designed for specific measurements, they can't detect unforeseen pollutants and determine cumulative effect of different pollutants. Significant problem is the coverage – measurements require expensive equipment. Therefore, the measurement stations are usually located in few spots, where it is most likely that the pollution levels would exceed in regulations defined values – weak and diffuse emission sources are not taken into account.

The alternative is bioindication – pollution level determination using living organisms – bioindicators. By applying methods of bioindication, it is not possible to make measurements of air pollutants concentrations, though it is an effective tool to evaluate such factors as exposure, dose and bioaccumulation, which cannot be effectively done using conventional technologies. Consequently, the parallel use of bioindication to existing monitoring networks would provide much realistic information about air pollution, enabling an evaluation of various pollutants simultaneous exposure caused cumulative effect. As bioindication does not require specific and expensive equipment, it would allow covering of all surveyed area, comprising the weak and diffuse emission sources. There are many bioindication methods, developed for air pollution assessment, but they are used mostly in individual evaluations – usually for scientific purposes. So far potential usage of bioindication as a current air pollution monitoring network's equivalent

solution has not been studied. Therefore, the aim of the research was to assess a variety of bioindication methods for air pollution determination and their applications in air pollution monitoring.

Materials and Methods

During the research, commonly used bioindication methods were selected based on their popularity in scientific literature in 2012, as well as they were assessed using theoretical analysis method in order to determine their strong and weak points in air pollution monitoring.

Bioindication for air pollution determination

The most commonly used bioindicators are plants because they are sedentary and damage caused by pollution is easily noticeable (Falla et al., 2000). In air pollution determination lichens are widely used – symbiotic organisms consisting of algae and fungi. This can be explained by the fact that pollution effects on lichens have been widely studied. First idea that lichens are influenced by air pollution was proposed by E. Darvin in 1790 when he studied lichen flora near foundries at the North Wales (Nimis et al., 2002). Since then, the study of lichens as bioindicators has increased rapidly, reaching the highest point in the 60th years of 20th century. Today, it has evolved into a separate branch of bioindication – lichenoindication. Lichenoindication methods can be divided into three major groups:

- Biochemistry based methods – biochemical analysis of changes caused by pollution;
- Quantitative evaluation of lichen flora in order to calculate air pollution index value;
- Qualitative evaluation of lichen flora when relation between pollution levels and particular lichen species are predefined.

An example of biochemistry based methods is A.G. Levin and M.L. Pignata method (1995). In the city of Cordoba, Argentina, the lichen *Ramalina ecklonii* was transplanted to 24 different urban sites. Then, lichen samples were collected from a 'clean' site in the north-west of the city and hung in nylon bags at a height of three m for eight weeks, prior to analysis. Chlorophyll, phaeophytin, conjugated dienes concentration, soluble protein content and thalli sulphur content were used as indicators of air pollution. The result of this study was Pollution Index (PI) equation, defined as follows:

$$PI = \left(\frac{Pa}{Ca} + \frac{St}{Sc}\right) \times \frac{CDt}{CDc} \quad (1)$$

where:

Pa – phaeophytin-a concentration (mg g^{-1} dry mass);
Ca – chlorophyll-a content (mg g^{-1} dry mass);
St – sulphur content of transplant (mg g^{-1} dry mass);
Sc – sulphur content of control lichen (mg g^{-1} dry mass);
CDt – conjugated diene in transplant (mg g^{-1} dry mass);
CDc – conjugated diene in control (mg g^{-1} dry mass).

Apparently, the biochemistry based methods are complex, as they require a specific laboratory equipment and knowledge. In addition, these methods are often related to particular species. Therefore, they can only be used in a specific geographic region where given species are present.

Quantitative evaluation of lichen flora is much simpler. The most common quantitative lichenoindication method is Index of Air Purity (IAP) (LeBlanc and De Sloover, 1970):

$$IAP = \sum_{1}^{n} \frac{(Q \times f)}{10} \quad (2)$$

where:

n = number of species present at a site;
f = frequency (cover) of the species (scale of 1 to 5);
Q = ecological index of each species i.e. the mean number of other lichen species growing with the species under study in the surveyed area.

Value f (frequency) can be determined visually while the value Q (ecological index), is calculated by following equation:

$$Q = \frac{\sum_{j=1}^{m} \sum_{i=1}^{n} S_{ij}}{m} \quad (3)$$

where

n – number of species;
m – number of stations where the species of interest is present;
S_{ij} – equals 1 if species i is present at station j (and species i is not the species of interest).

This method is very simple to use and unlike biochemistry-based methods does not require specific and expensive equipment. The IAP method is not attracted to any particular geographical region because whole lichen flora is evaluated and all data necessary for calculations are obtained in the surveyed area.

Qualitative evaluation of lichen flora is even simpler. Well known example is D.L. Hawksworth and F. Rose (1970) scale, developed in Great Britain, based on studies relating to SO_2 impact on lichens.

The scale consists of 80 lichen species divided into eleven correlation classes according to various rates of air pollution. Such species classification by pollution level is one of most discussed issues in literature (Conti and Cecchetti, 2001), because correlations are affected by environmental, climatic factors and geographic region. A major drawback, compared to quantitative methods is the fact that qualitative scale describes only one type of pollution - usually SO_2. Therefore, it is not possible to assess the cumulative effect, which is one of the main advantages of bioindication over electronic sensors. Taking this problem in to account, different scales have been developed. Take, for example, C. Van Haluwyn and M. Lerond (1986) scale in which class correlation is not directly related to the SO_2 concentrationsbut to lichen sensitivity to pollution in general. However, this scale is also affected by environmental factors and geographic region restrictions.

Citizen science approach in data collection

In bioindication one of the most important stages is data collection in field studies – necessary species location, assessment of its condition and obtained data recording. This is usually time consuming, especially if the surveyed area is very large. In such cases, when extensive data acquisition in field studies is required, often the so called citizen science approach is used – volunteers (non specialists) involvement in data collection for scientific research purposes (Newman et al., 2011).

Citizen science projects operate on the following scheme:

- The project organizers prepare instructions and present them to volunteers (communication usually takes place via Internet-based solutions);
- Volunteers collect necessary data by doing observations;
- Data are submitted to project organizers using the same solution as that of receiving instructions.

Thus, all the tasks that require specific qualification are done by project organizers while time consuming tasks, that do not require specific skills are assigned to volunteers. To ensure that this process is efficient, it is important to note some factors (Silvertown, 2009):

- Although the data processing and interpretation are usually done by experts or software-based solutions, data validation is also necessary in order to ensure that submitted data are correct and avoid wrong data submission and cyber vandalism in cases when Internet based solution are used;
- Instructions must be standardized and easy to understand;
- Project organizers must provide feedback to motivate and reward volunteers who are involved in the project.

Results and Discussion

One of the most significant problems of current air pollution monitoring networks is high costs, which is the reason why network coverage is often insufficient. Bioindication does not require specific and expensive equipment, while there is another kind of problem – human resources. To find and identify bioindicators, qualified professionals are needed who regularly survey the area being monitored. This can lead to serious problems if the monitored area is very large. A choice between large, but single investments in automatic monitoring stations or permanent costs by hiring specialists in bioindication variant has to be made.

One of solutions is to apply citizen science approach. Bioindication based air pollution assessment includes two stages where specific knowledge is required – data acquisition and data processing (Figure 1.)

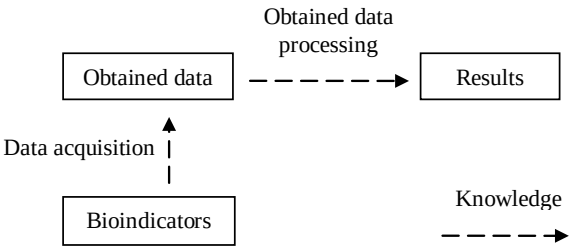

Figure 1. Information flow in bioindication based pollution assessment.

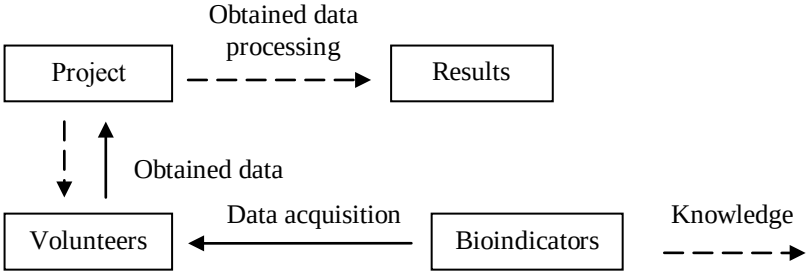

Figure 2. Information flow in bioindication based citizen science project.

Knowledge required for bioindication can be incorporated in appropriate citizen science project elements – data acquisition knowledge in instructions and knowledge required for obtained data processing in project data processing solution (Figure 2.).

Consequently, air pollution monitoring using bioindication and citizen science approach can be carried out as follows:

- Volunteers receive instructions – list of lichen species (explained in an understandable way for non-specialists) for identifying the species, and pollution caused damage recognition signs;
- Volunteers do all necessary observations – find and identify lichen species and at the end submit obtained data to processing;
- Data are processed according to the methodology, building dynamic database on pollution levels in surveyed area.

The most important elements in this process are instructions and the methodology used. Data acquisition depends on quality of instructions while data processing and validity depends on the methodology used. Therefore, methodology in citizen science project must meet two requirements:

- According to it, clearly defined and easily understandable instructions can be developed;
- Used data must be obtainable only on basis of information included in developed instructions without additional knowledge.

Most of the currently used bioindication methods do not meet these requirements. Data necessary for biochemistry based methods are obtained only in the laboratory; therefore, volunteers cannot be involved. Even if volunteers collect lichen samples for submission to the laboratory for further analysis, such a process would not be efficient because specific knowledge is still needed – lichens must be separated from substrate, placed in nylon bags and immediately delivered to the laboratory. Quantitative methods are more appropriate. IAP method is one that is especially outstanding. Using this method, only two values must be determined – lichen species and frequency (in ordinal scale) of these species. However, the problem is calculation procedure itself. The ecological index value in IAP equation is variable – it must be calculated during the study. To do this, all lichen species in surveyed site must be found and identified. This factor makes the development of instructions for data collection almost impossible, because such amount of knowledge cannot be included in short and easily understandable instructions. From the citizen science view point, qualitative methods are the most compliant – small and fixed number of lichen species is used and one species is enough to interpret it as consistent air pollution level. However, qualitative methods are also the most controversial, because their accuracy and practical application is a frequent topic of discussion in the literature. In addition, qualitative methods are generally designed for evaluation of single pollution type, so they are not designed to evaluate the cumulative effect, but that effect is one of the main objectives why to use bioindication in air pollution monitoring.

Merging of bioindiction and citizen science approach can lead to a new kind of air pollution monitoring programs, allowing more realistic assessment of air pollution and its changes, because information is obtained by using live organisms. Combining the data from bioindication survey with data from current monitoring stations networks, would supply regulatory authorities with better and more detailed information on air pollution; thus, not only concentrations of different types of pollution can be evaluated, but also its impact on live organisms. Therefore, the development of citizen science suitable bioindication method with data collection and processing that are carried out according to simple instructions which are easy to understand without any prior knowledge and experience in the field of bioindication is necessary.

Conclusions

1. Bioindication usage in air pollution monitoring can be time consuming and may require large human resources. This can lead to serious problems if the monitored area is very large, thus creating a situation when it is vital to make a choice between large but single investments in automatic monitoring stations or permanent costs by hiring specialists in bioindication variant.
2. Usage of bioindication as a current air pollution monitoring networks equivalent solution can be combined with citizen science approach. Thus, bioindication based air pollution evaluation could be less time consuming and requirements for human resources would be reduced. Bioindication becomes more appropriate for air pollution monitoring needs.
3. Bioindication method used in citizen science project must be sufficiently simple, so that non-specialists without any experience in bioindication can understand it.
4. According to the method, clearly defined and easily understandable instructions for data collecting, based only on information incorporated in the instructions must be developed.

5. Therefore, the development of citizen science suitable bioindication method is necessary. It would allow the development of a new kind of air pollution monitoring programs in which not only concentrations of different types of pollution can be evaluated, but also its impact on live organisms.

References

1. Conti M.E., Cecchetti G. (2001) Biological monitoring: lichens as bioindicators of air pollution assessment – a review. *Environmental Pollution*, 114, pp. 471–492.
2. Falla J., Gilly P.L., Henryson M., Morlot D., Ferard J.F. (2000) Biological Air Quality Monitoring: A Review. *Environmental Monitoring and Assessment*, 64, pp. 627–644.
3. 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.
4. Hodin A., Hertz P.A. (1996) Evaluation de la Pollution Atmosphérique Industrielle et Urbaine à Partir des Données Météorologiques de Routine (Evaluation of the Urban and Industrial Air Pollution from Routine Meteorological Data). In: *L'écotoxicologie du compartiment aérien*, Congress, Rouen, France, Société d'Ecotoxicologie Fondamentale et Appliquée, pp. 103–112. (in French).
5. Leblanc F., DeSloover J. (1970) Relations between industrialization and the distribution and growth of epiphytic lichens and mosses in Montreal. *Canadian Journal of Botany*, 48, pp. 1485–1496.
6. Levin A.G., Pignata M.L. (1995) *Ramalina ecklonii* as a bioindicator of atmospheric pollution in Argentina. *Canadian Journal of Botany*, 73, pp. 1196–1202.
7. Newman G., Graham J., Crall A., Laituri M. (2011) The art and science of multi scale citizen science support. *Ecological Informatics*, 6, pp. 217–227.
8. 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.
9. Silvertown J. (2009) A new dawn for citizen science. *Trends in Ecology and Evolution*, 24, pp. 467–471.
10. Van Haluwyn C., Lerond M. (1986) Lichensociologie et qualite de l'aire: protocole operatoire et limites (Lichensociologia and quality of the area: limits and operative protocol). *Crytogamie Bryologie et Lichenologie*, 9, pp. 313–336. (in French).

CHURCHYARD ELEMENTS IN LATGALE UPLAND

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Abstract
Churchyard of Latgale Upland is one of the most important parts of cultural historic space of Latvia. The study is based on the materials from expedition made in summer and autumn 2011, as well as on literary studies. Architecturally compositional form of the church is a key part of the landscape, supplemented by other landscape elements. Research and evaluation of the individual elements give specific cultural space characteristics of each investigated area. Visibility in the main view points and links with residential buildings for the churchyard is vital. Each study of landscape area schemes formation is based not only on the church as a domination point expression. Separate churchyard elements - crucifixes, procession paths, burial area, meditation area and a planting in church gardens - are important in describing churchyards. The aim of the research was to find most common elements in churchyards to establish general guidelines for recording and evaluation of the churchyard in Latgale Upland in future. In perspective that could be used as basis for making the landscape typology. Results showed typical landscape elements in the churchyard. In describing churchyards is important to divide typical and unique elements. The research provides information that is important for the further local territorial development plans, focusing attention on the region's cultural values and identity preservation.
Key words: churchyard, landscape elements, landscape typology, regional identity.

Introduction

Latgale Upland is placed in the southern part of Latvia. This territory is rich with lakes and has a very picturesque landscape. Church landscape is an important cultural historic part of the history of Latgale. The church landscape has changed considerably in the last years. Trees have been cut a lot and new ones have been planted again. The use of the land surrounding churches has changed too. But this process has been done without any guidance.

The emphasis shifts from landscape as a product of culture to landscape as an agent producing and enriching culture (Comer, 1999). It is important to find the part directly developed by people. It has to be made in accordance with nowadays and not forgetting about history. Landscape has to be made while taking both the traditions and contemporary changes into account.

Latgale has had to start its life over from scratch five times, mainly because each time there has been a complete change of ethnicity and sociocultural field (Fjodorovs, 2009). The sacral landscape of Latgale is unique; it has a different development history than the rest of Latvia (Pidža, 2011). As it is characteristic to Latgale, we can find all the traditional confessions there (Catholic, Orthodox, Lutheran, Old believers) and holy sites of Moses believers (Kaminska and Bistere, 2011). These differences make these landscapes even more special, and it is important to improve our knowledge about this part of the cultural historic places.

On the one hand, the church garden is used only on Sundays, and the parishioners are not outdoors then. But, on the other hand, it is an object for tourism attraction, especially in Latgale, these places can be used for gatherings and relaxing walks.

Historic buildings form the most visible and tangible of all aspects of the historic environment. They are a finite resource and cannot undergo change without cultural loss (Morris and Therivel, 2009).

There are different ways of reading landscapes. For a long time, the methods used by students of landscapes, notably landscape architects and geographers were highly individual (Taylor et al., 1987). To be sure, reading landscapes is not as easy as reading books, and for two reasons. First, ordinary landscape seems messy and disorganized (Peirce, 1979). New researches in sphere of religion have been started in many fields. Geographical research on religion has grown immensely in the last decade, and many earlier silences have become nascent areas of research or even areas of emphasis (Kong, 2010). The quality of scenery can be evaluated by two different sorts of techniques - preference techniques and surrogate component techniques (Crofts, 1975).

The second one is being discussed in this paper. The technique is based on the identification and measurement of those physical components of the landscape which are regarded as surrogates of scenic quality. The individual components are isolated, their identification and measurement discussed and their combined utility within existing techniques evaluated (Crofts, 1975). Church landscapes are designed cultural landscapes (General, 1999). As they are manmade, we are responsible for their development and preservation.

Since the patterns we see are formed from the arrangement of different components, it is an obvious

starting point to describe and classify these components (Bell, 2004). There are numerous character-defining features of the landscape: topography, vegetation, circulation, water features, buildings and structures, site furnishing and objects (General, 1999). Landscape elements are individual elements that make up the landscape, including prominent or eye-catching features such as hills, valleys, woods, trees and hedges, ponds, buildings and roads. They are generally quantifiable and can be easily described. It is necessary to consider this aspect of the landscape to reach an understanding of the effect of development on a landscape resource (Guidelines, 2002).

At this stage of the research it is important to understand precisely what we need to look at and what we could possibly find. The aim of the research was to find most common elements in churchyards to establish general guidelines for recording and evaluation of the churchyard in Latgale Upland in future. In perspective that could be used as a basis for making the landscape typology.

Church building is important in landscape, because it is a visible sign to show beliefs with a building that is devoted to God (Kaminska and Bistere, 2011). And these buildings – churches - are supplemented with certain elements depending on the confession. In most of the cases, the landscape around the church has been developed without taking the churchyard into account. Unfortunately, the historical buildings have had to suffer because of the lack of caution.

Written fixation or description of landscape and it's elements is important, because photographs do not accurately represent what is seen by the human eye, as it can distinguish elements by using a contrast range of about 1,000 shades between black and white, whereas a picture of the same view taken with a camera and shown on a computer screen will use only about 100 shades. This range of contrast is reduced to as low as 12 shades when printed on paper (Visual, 2006).

Elements are functional, decorative and they can be symbolic too. And symbolic meaning of these elements is a part of landscape identity (Ņitavska, 2011). Landscape units are sections of landscape with different dimensions and chorological structure. Each landscape unit can be distinguished by its own, relatively stable set of natural and anthropogenic factors, and its functional expression is characterized by a specific complex of landscape elements (Nimann, 1982; Krönert et al., 2001). Visual impact capturing has a limitation, which is why field trip is very important. What can be found and seen at a place is much more than what can be captured by photography.

Materials and Methods

Latgale Upland was chosen as a research territory (Figure 1). Expedition to the churchyards of Latgale Upland was done from June till October in 2011, when a survey of 68 churches in the Latgale Upland was carried out. Churchyards were chosen randomly from rural and urban landscapes. Almost all churchyards, which can be found in Latgale Upland, were surveyed. The survey was done in good weather conditions during the daytime. Before going on the field trip, an object survey table was created, based on previous researches. Survey table consisted of three parts. In the first part the object had to be named, and its placement according to the road and urban places defined. The second part listed all separate churchyard elements that were expected to be found in the churchyard – fence, benches, trees in the perimeter of the church building, free standing bell tower, crucifix, churchyards, burials near church territory. Toward each element a note was made whether it is or it is not in the churchyard. In third part, the landscape was

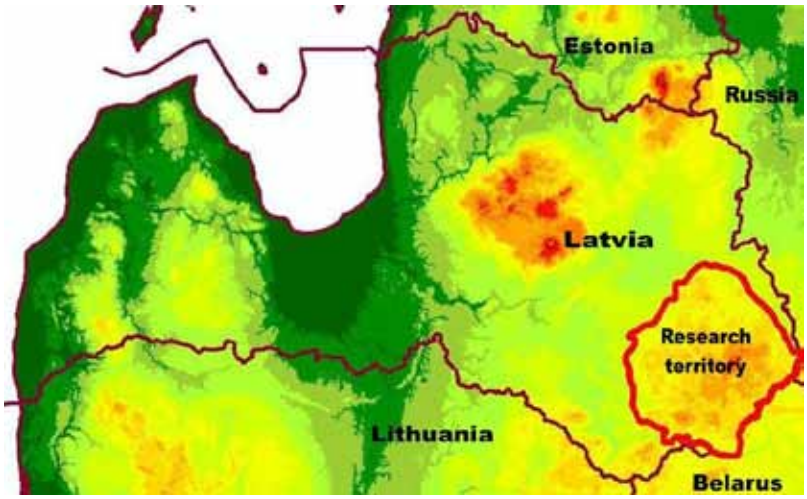

Figure 1. The location of research territory.

described – wideness, dominant, symmetry. Results of table second part were used for this research. During the expedition, written fixations supplemented with fixations by photography were used. In this part of research during the survey process it became clear whether the separate churchyard elements were present or not.

Results and Discussion

In the survey process of 68 churchyards it was found out that the typical elements that we expected to find in church gardens really were there, with a few exceptions. Even if there are some similarities, very important is that each place is specific and has its own individual elements, such as religious art objects or planting structures. These cultural landscapes are mostly filled with specific elements, characteristic only for churchyard.

The results were obtained in a profound survey process without trying to use some common methods from landscape analysis. This is the expert and psychophysical way, which emphasizes landscape features. All these elements are part of the landscape transformation process.

Culture interface deals with the differences in landscape values resulting from different cultural perspectives. It is the way different cultures perceive and interpret landscape that is in focus, as well as the way cultures give landscape the symbolic meanings (Palang and Fry, 2003). Historic landscape includes not only buildings, but although circulation features as roads and furnishing, including fences, benches, lights and sculptural objects (Charles, 2004). All churchyard elements are result of cultural expression. Outdoor elements of churchyard are as philosophical and compositional continuation of church building. The idea of symbolic garden design has its origins in ancient civilization. Each church garden in Latgale Upland uses slightly different elements to provide the same symbolic information. The research is focused on man-made landscape elements. Small-scale elements of churchyard can be decorative or functional or both.

Fences are the most common elements in churchyard; 76% of churchyards included in research had fences (Table 1). Probably nobody can imagine the world without fences. Fencing is mostly used for church garden boundary demarcation, although it delineates ownership and land use area. Almost all churchyards have fences or hedgerows. They are organizational elements of the landscape. These functional and visual relationships between spaces are integral to the historic character of a property (General, 1999). Sometimes there is no fence, only gates. These are decorative, functional and symbolic elements of churchyard. Fencing although symbolizes boundaries. It is not so much boundaries for land property, but more between mental and material world. Gates are visual dominant elements of the churchyard, which are seen from distance (Figures 2, 3, 4).

Figure 2. Fence and gates of Kraslava catholic church.

Figure 3. Fence and gates of Berzgale church.

Figure 4. Fence and gates of Nīdermuiža church.

Second most common element in churchyards is benches (Table 1). Benches are used mostly around crucifixes or in front gardens. They are not placed symmetrically or in any other order. Benches are only functional elements. Benches together with crucifixes form meditation gardens. These small meditation gardens shape separate independent entities (Figures 5, 6, 7).

Figure 5. Benches and crucifixes in Berzgale church garden.

Figure 6. Benches and crucifixes in Indricas church garden and river Daugava in background.

Figure 7. Benches and crucifixes in Dubna church garden.

Crucifixes in rural landscape of Latgale are a phenomenon. But in churchyards of catholic confession it is almost an inherent part. The crucifix is very common for catholic landscapes (Table 1). This is the most symbolic element of churchyards, but it is also decorative and functional.

Gardens are found in third part of the surveyed landscapes (Table 1). Most of them are small. Burials are not widely seen in churchyards and when they are there, they are more like memorial places or signs. Burials in Latgale are invisible graves in the churchyard between flowers and trees.

Landscape of Latgale is not possible to imagine without trees. Trees are decorative, functional and with historically developed and enduring symbolic meaning. In small-scale churchyards, trees in the perimeter of church building are as frequent as crucifixes (Table 1). It is known that in urban places and near the building trees make more harm, than good. Trees can have bad effects on their surrounding structures and buildings. It is incorrect to plant any tree touching the building. The shadow of the trees should not fall on the buildings. The best way to keep the trees at bay is to cut off the branches of trees that touch the buildings. Damage mainly can be made by roots and falling branches.

Third part of research objects had trees in the perimeter of building (Figure 8). Sometimes historical trees in the perimeter of building have been cut down (Figure 9). Trees that are historic or landmark trees, strong species or trees well situated in landscape can be maintained. But if trees are weak species, short life species, trees that block desirable views, they have to be cut down. Hedgerow trees act as property boundaries. Usually, in churchyards of Latgale Upland, fences which are supplemented by hedgerow are used (Figure 10).

Figure 8. Trees in the perimeter of Kombuļi church building.

Figure 9. Cut trees in the perimeter of Peipiņu church building.

Figure 10. New planted trees in the perimeter of Rogovka church building.

Free-standing bell towers or campaniles are architectural features that are mainly typical for catholic churchyards. The bells in the free-standing towers are for calling people to congregate. Free-standing bell towers are frequently found in the churchyards of Latgale Upland - in 29% of surveyedlandscapes (Figures 11, 12, 13).

Figure 11. Free-standing bell tower in Borovka.

Figure 12. Free-standing bell tower in Šķaune.

Figure 13. Free-standing bell tower with a unique construction in Rečeņi.

Also an important part is burials near the churchyard territory, because churchyards are common in many countries but not always there are separate burials. Burials near the churchyard territory were in 22% of surveyed landscapes (Table 1).

Table 1

Occurrence of typical churchyard elements

Element	Occurrence (%)
Fence	76
Benches	59
Crucifix	41
Churchyards	35
Trees in perimeter of church building	34
Free-standing bell tower	29
Burials near church territory	22

In local territorial development plans it is important to focus attention on the region's cultural values and identity preservation, especially in Latgale region, where historical cultural values are the main tourist attraction objects. Attraction consists not only of the church building, but of the other churchyard elements too. Landscape elements, the same as landscape, act as stimuli to which observers respond (Taylor et al., 1987). To describe elements we have to look at landscape even in smaller scale. Elements are not separate things but integrations of systems (Motloch, 2000). Buildings have their own infrastructure, trees have their root system and roads have their network. In this research, elements were taken separately from all systems and taken as a starting point for these systems and further researches.

The study of the cultural interface in landscape research is extremely important for the understanding

of how landscape evolved in the past and how conflicts may arise in the future (Palang and Fry, 2003). Most of the features of churchyard we take as self-evident. With looking from a side we perceive more objective information and distance from imagination landscapes.

Conclusions

This is a small introduction in churchyard elements we could find in Latgale Upland. All described elements are found in the churchyards of Latgale Upland and are important characteristic elements. Churchyards are unique thanks to these specific elements. In perspective, main guidelines of this research could be used as basis for making the churchyard element typology. The research provides information that is important for the further local territorial development plans. Element fixation makes detailed description possible. In further research there are many other elements that have to be included in inventory. Also research inventory needs a deeper survey not only of element types but also of their different forms.

References

1. Bell S. (2004) *Elements of visual design in the landscape 2nd edition*. Spoon Press, London, 196 p.
2. Charles A.B. (2004) Protecting Cultural Landscapes: Planning, Treatment and Management of Historic Landscapes. In: *The preservation of historic architecture: the U.S. government's official guidelines for preserving historic homes.* The Lyons Press, United States of America, pp. 433–453.
3. Comer J. (1999) *Recovering landscape: essays in contemporary landscape architecture*. Princeton Architectural Press, New York, 287 p.
4. Crofts R.S. (1975) The Landscape Component Approach to Landscape Evaluation. *Transactions of the Institute of British Geographers,* No. 66, Blackwell Publishing, pp. 124–129.
5. *Visual Representation of Windfarms Good Practice Guide, Scottish Natural Heritage, The Scottish Renewables Forum and the Scottish Society of Directors of Plannin* (2006) Envision and horner + maclennan Available at: www.snh.org.uk/pdfs/publications/heritagemanagement/Visual%20Representation%20of%20windfarms%20-%20excerpt.pdf, 13 December 2011.
6. Fjodorovs F. (2009) The spiritual space of Latgale, *Latgale as a culture borderzone: comperative studies Vol II (1)*. Daugavpils, Saule, University of Daugavpils pp. 9–19.
7. *General Guidelines for Identifying and Evaluating Historic Landscapes, environmental program, California,* (1999) California department of transportation Sacramento. Available at: www.dot.ca.gov/ser/downloads/cultural /languide.pdf, 10 November 2011.
8. Kaminska R., Bistere A. (2011) *Sakrālās arhitektūras un mākslas mantojums Rēzeknes pilsētā un rajonā* (The Heritage of Religious Architecture and Art in Rēzekne Town and District). Neputns, Rīga, 8. lpp. (in Latvian).
9. Kong L. (2010) *Global shifts, theoretical shifts: Changing geographies of religion. Singapore: National University of Singapore.* Available at: http://phg.sagepub.com/content/early/2010/03/30/0309132510362602.abstract, 10 December 2010.
10. Krönert R., Steinhardt U., Volk M. (2001) *Landscape balance and landscape assessment*. Springer, Germany, pp. 9.
11. *Guidelines for Landscape and Visual Impact Assessment, 2nd Edition* (2002) Landscape Institute & Institute of Environmental Management & Assessment, Spon Press, London, 166 p.
12. Palang H., Fry G. (2003) Landscape interfaces. In: Palang H., Fry G. (eds) *Landscape interfaces: cultural heritage in changing landscapes,* Landscape series vol.1, Kluwer Academic Publishers, Dordrecht, pp. 1–9.
13. Pidža M. (2011) Visual quality evaluation approaches of sacral landscape of Latgale. In: Latvia University of Agriculture (eds) *Research for Rural Development 2011, Annual 17th International Scientific Conference Proceedings*, Volume No2, Latvia University of Agriculture, Jelgava, LLU, pp. 189–193.
14. Peirce F.L. (1979) Axioms for reading the landscape. Some guides to the American scene. In: Meinig D.W. (eds) *The interpretation of ordinary landscapes*. Oxford university press, New York, Oxford, pp. 11–32.
15. Morris P., Therivel R. (2009) Heritage. In: Morris P., Therivel R. (eds) *Methods of environmental impact assessment 3rd edition.* Routledge, New York, pp. 145–173.
16. Motloch J.L. (2000) *Introduction to landscape design*. John Wiley and Sons, United States of America, 369 p.
17. Nimann E. (1982) *Metodik zur Bestimmung der Eignung, Leistung and Belastbarkeit von Landschaftselementen und Landschaftseinheiten Wissenschaftliche Mitteilunger* (Landscape element and

landscape unity scientific recognitions – methodology for determination propriety, efficiency and load). IGG, Leipzig, 84 S. (in German).

18. Ņitavska N. (2011) The method of landscape identity assessment. In: Latvia University of Agriculture (eds) *Research for Rural Development 2011, Annual 17th International Scientific Conference Proceedings,* Volume No2. Jelgava, LLU, pp. 175–181.
19. Taylor J.G., Zube E.H., Sell J.L. (1987) Landscape assessment and perception research methods. In: Bechtel R.B., Marans R.W., Michelson W. (eds) *Methods in Environmental and Behavioural Research*, NY, VNR, New York, pp. 361–391.

CONTAMINATION PROBLEMS IN FORMER MILITARY AREAS: CASE STUDY IN RIGA

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Abstract
Contamination of urban areas is directly connected with the lack of adequate waste management planning. Problems mostly arise in former military bases, garages, warehouses and areas with other facilities. For many decades environmental problems caused by pollution in areas of military use were not managed in Latvia. The aim of this research is to assess visual environmental quality and study heavy metal contents in soil of 'Jaunais Mežaparks' after demolishing works in the capital of Latvia – Riga, as well as to provide comparison to the former military 'Daugavgrīva' site. Research was carried out from November 2011 to February 2012 by soil sampling and further analysis and comparison of the heavy metal content in soil with target and boundary levels in legislation. 'Jaunais Mežaparks' is a former military area which is planned to be reused in future. The former military site is planned to be used as the residential neighborhood and is situated close to important recreational object in Mežaparks area – Lake Ķīšezers. According to Riga Development Plan old military sites must be remediated in accordance with environmental legislation if the contamination exceeds critical concentration values. Thus, this case study includes assessment of visual pollution as well as soil heavy metal contamination study. Recommended actions as well as direct remediation technologies to reduce the poisonous impact of contamination to environment in this area are proposed.
Key words: soil sampling, remediation, heavy metals, former military area.

Introduction

Soil and groundwater are environmental compartments that are primarily influenced by industrial development with increasing amount of industrial wastes and inadequate dumping of them. It causes a large number of contaminated sites that are disseminated in post industrialized countries (Prokop et al., 2000; Critto et al., 2006). Environmental contamination as a result of anthropogenic activities is not a recent phenomenon. Contaminated sites can be found in functioning as well as abandoned industrial (brownfield) territories, landfills, residential areas with historical contamination, road sides and rarely in polluted sites by natural activities. A special attention should be paid to the contamination in former military sites, because in many cases this contamination is most problematic for remediation and is disturbing the territorial planning of cities.

After the World War II more than 1,000 units of Soviet Army forces were located in about 600 military sites that cover ~ 10% of Latvia territory. The largest firing-grounds were Zvārde, Liepaja Navy port (Karaosta), Rudbārži missile base, and Lielvārde airfield. Site pre-investigations and remediation have been carried out in some of the former military territories, e.g. Rumbula airfield where soil and groundwater was contaminated with oil products. A total area of 6 ha was contaminated with oil products and during 2000-2002 1730 m^3 of contaminated groundwater (~80 m^3 of pure oil product) was pumped out (Piesārņoto un potenciāli piesārņoto vietu reģistrs, 2001 – updated data base available on the internet). Contamination with heavy metals, toxic organic substances, and also with oil products was determined in about 11 military territories. In spite of the remaining historical contamination, some of these territories are readjusted for the use of another purpose, e.g. the area of the Riga Freeport (Burlakovs and Vircavs, 2011).

National Register of contaminated territories of Latvia provides the list of priority importance areas to be remediated and re-cultivated. Methods and procedures for the ascertaining of polluted and potentially polluted sites, as well as the procedures for financing, conditions for data collection and utilization are regulated by the Cabinet of Ministers Regulations No. 483 adopted on November 20, 2001 'Inventory and registration of contaminated and potentially contaminated areas'. There are plenty of sites not mentioned on the lis, those are still unknown to public - whether and to what degree they are polluted. The former military area now is being demolished – the territory 'Jaunais Mežaparks' according to the Riga City Development Plan (Rīgas attīstības plāns, 2006) is planned as the commercial and residential housing area with up to 25 -storey high buildings t with approximately 10 000 people capacity.

In former military areas the quantity of soil and groundwater pollution is often undetected. An important step in order to gain information about the area is to give visual estimation of the area, collect information about historical contamination sources and use preliminary soil and groundwater contamination studies. Provisional inspection must be done before the start of the investigation field works, in order to estimate the situation and select drilling points and points for sampling. The territorial

plan and placement of potentially hazardous objects must be taken into account for the selection of study sites as well as underground communications, relief characteristics, amelioration, geological and hydrogeological conditions are important.

Research was started in November 2011 and finished in February 2012; the aim of it was to assess the environmental situation and heavy metal contents in soil in 'Jaunais Mežaparks' area after demolishing works and give comparison to the former military site 'Daugavgrīva'.

Materials and Methods

Description and historical land use of the territory. The area is situated in the northern part of Riga (Fig. 1, 2), total area is approximately 31.6 ha. This area according to Riga City Development Plan is proposed for commercial and residential use in future. Detailed planning is needed as well as clean-up of the site before more detailed planning is applied.

The territory is located in Baltic Ice Lake plain with mainly sand dunes geomorphology. The amelioration system (Mailes Ditch) is made for drainage purposes in the area (Fig. 2). Inhabitants of neighboring urban areas recall that this area in Soviet times was always used as the military land, in which chemical warehouses and military garages were located. During 90-ties of the 20th century it was abandoned, and in 2011 the removing of warehouses and cleaning of the area from buildings started. Site cleanup can be done without special default remediation, because it is not on the list of National Register. When Riga City Development Plan in this area will be implemented in life, the environmental assessment of the soil quality according to the legislation of Latvia should be done.

In order to estimate the situation and select appropriate points for representative sampling with drilling method, the visual inspection and photographic evidence was collected before and during the investigation field works in the case study 'Jaunais Mežaparks'.

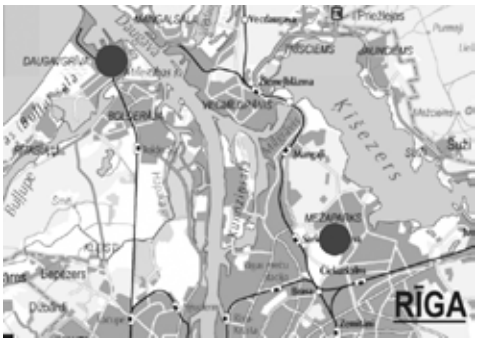

Figure 1. Location of former military areas 'Jaunais Mežaparks' and 'Daugavgrīva' in Riga, Latvia (approximate distance between points 6-7 km) (map source 'Jāņa Sēta').

To estimate the soil quality at the investigation territory, sampling of soil was taken from the upper part of the soil in the depth of 0.40 m. A hand probe was used for this purpose. Soil samples with special disposable rubber gloves were taken from the probe and put in chemically clean polythene sampling bags. The sampling territory was split into 7 sub-areas (Fig. 2), each of 4-5 ha area on average. I25 samples were taken from all these sub-areas and mixed together for the joint sample. Totally 175 soil samples were taken on 13th of November, 2011, mixed in 7 joint soil samples for each of sub-area, then in constant temperature taken to the laboratory for the heavy metal laboratory analysis.

Figure 2. 'Jaunais Mežaparks' former military study area: sampling sub-areas with numbers referred to results in Table 1. Arrow shows groundwater flow direction in Mailes Ditch amelioration system. (area within borders 31.6 ha) (source 'Jāņa Sēta').

One joint sample was taken in deeper horizon (0.4-1.0 m) of the soil. Seven drilling points in 7 sub-areas were selected, and 7 deeper samples were mixed in a joint sample in order to have the information about the average heavy metal content in the deeper interval for the whole area. Sub-areas were chosen according to visual assessment principle, in order to get more representative samples from each. Samples taken in the area No. 4 and samples from deeper interval 0.4-1.0 m were taken in double for verification of the result (4-1 and 4-2; L-1 and L-2).

Samples were dried, extracted in HNO_3 solution and delivered to the laboratory for atomic absorption

spectroscopy analysis. Analysis for Na, Mg, K, Ca, Fe, Mn and heavy metal concentrations (Cu, Pb, Zn, Ni, Cd, Cr, Co) was performed in the laboratory of the University of Latvia.

The study at the Riga Freeport in 'Daugavgrīva' was performed in a similar way in January 2012 at the former military area nearby the inlet of the Daugava River into the Gulf of Riga (Fig. 1). Sampling was done from one drilling site (FR I and FR-L samples) with a mechanical drilling vehicle 'Nordmeyer' with mounted auger of 140 mm diameter. A hand probe was used in a similar way like in 'Jaunais Mežaparks' case. 'Daugavgrīva' territory was not split in sub-areas; therefore, more detailed map is not given.

Dispersion of heavy metal concentrations in sandy soils was taken according to pollution categories from Instructions of the Cabinet of Ministers Nr. 804 'Instructions on Environmental Quality Standards for Soils' (Noteikumi par augsnes un grunts kvalitātes normatīviem, 2005), where: A is the target value, which shows value of adequate soil quality; B is the precaution boundary limit showing pollution level, when surpassing it there is a possibility of the negative impact on human's health and environmental quality; C – the critical boundary limit, when functional qualities of soils are distorted or pollution have the direct threat to human's health or environmental quality, in case of surpassing it rehabilitation works must be done at the place.

Afterwards data analysis was done, the laboratory results were compared to the target as well as precaution and critical boundary levels.

Results and Discussion

Comparison of two former military areas in 'Jaunais Mežaparks' and Daugavgrīva (Fig. 1) is drawing trends that former military areas has slightly higher ordinary metal and heavy metal contents in soil due to previous activities in the past. Visual assessment and photographic evidence provided material allowing to make assumption that area is possibly polluted also with oil products. The contamination with metals is not very high like in areas of directly industrial soil as in most contaminated parts of Riga and Liepāja and Riga harbors (Piesārņoto un potenciāli piesārņoto vietu reģistrs – updated data base available on the internet), but still is exceeding target values. One of the most polluted areas is, e.g., Liepaja Navy Port (Karosta) (Liepaja Navy Port..., 1996). The obtained results show that sediments are mostly polluted with Cd, Cu, Pb, Hg and Zn. The geoaccumulation and pollution load indexes were used in order to compare the contamination levels in the Liepaja and Riga harbors (Vircavs, 2008). In 'Jaunais Mežaparks' and

Table 1

Concentrations of metals (mg kg^{-1}) in soil upper layer: 'Jaunais Mežaparks' and former military area in 'Daugavgrīva'

No.	Sampling interval, m	Heavy metal concentration							Concentration of other metal elements		
		Cd	Cr	Cu	Zn	Pb	Ni	Co	Mn	Fe	Mg
1	0.0 – 0.4	<0.2	15.0	4.6	21.7	18.0	7.0	0.6	65.0	1724	1264
2	0.0 – 0.4	<0.2	<11.0	1.5	5.6	13.0	<6.0	0.4	74.0	864	4642
3	0.0 – 0.4	<0.2	12.0	9.9	118.5	42.0	<6.0	0.8	63.0	2218	1563
4-1	0.0 – 0.4	0.5	16.0	**158.3**	**472.6**	**87.0**	8.0	**2.7**	**183.0**	**14468**	1078
4-2	0.0 – 0.4	0.6	15.0	**127.3**	**401.1**	**100.0**	8.0	**2.4**	**135.0**	**11461**	1333
5	0.0 – 0.4	<0.2	12.0	9.9	118.5	42.0	<6.0	0.8	63.0	2218	1563
6	0.0 – 0.4	<0.2	<11.0	5.1	19.1	9.0	<6.0	0.5	39.0	1368	415
7	0.0 – 0.4	<0.2	<11.0	3.3	14.0	6.0	<6.0	0.3	29.0	1064	289
-1	0.4 – 1.0	<0.2	<11.0	3.1	13.9	8.0	<6.0	0.6	32.0	1467	619
-2	0.4 – 1.0	<0.2	15.0	4.3	32.1	9.0	7.0	0.9	46.0	2307	1047
FR-I	0.4-1.0	0.15	24.0	14.4	116.5	41.5	13.5	1.4	**150.0**	2539	**56876**
FR-L	2.0-4.0	0.15	21.0	5.9	75.0	14.3	12.8	0.9	49.0	1853	7561
FR-Area	0.0-0.4	<0.1	22.0	18.0	115.0	69.0	13.0	1.0	61.0	3101	5697
Boundary limits	**A cat.**	0.08	4	4	16	13	3	-	-	-	-
	B cat.	3	150	30	250	75	50	-	-	-	-
	C cat.	**8**	**350**	**150**	**700**	**300**	**200**	**-**	**-**	**-**	**-**

'Daugavgrīva' cases this pollution is not so high and vast, but we can compare it with the so called phytophile geochemical soil associations containing elements with higher concentration of phytogenetic contents.

The table shows heavy metal concentrations in soil in the case study area in 'Jaunais Mežaparks'. Comparison with the technical study in 'Daugavgrīva' is given in Table 1 (codes FR).

Samples 1, 2, 3, 4-1, 4-2, 5, 6, 7, L-1 and L-2 were taken in 'Jaunais Mežaparks', but FR-I, FR-L and FR-Area in 'Daugavgrīva'. Results of heavy metal concentrations in most part of 'Jaunais Mežaparks' are above the target value (Table 1), Cr exceeds target value 3-4 times, Zn up to 7 times, Ni - 2 times, but most concerns should be addressed to the sampling sub-area No. 4 (Fig. 2). In this sub-area 3 elements are exceeding precaution boundary limit, the amount of Cu is very close to the critical boundary level. The average content of metals in soil is 3-7 times higher in this sub-area than in surrounding ones.

Possible, that it is influenced by anthropogenic atmospheric loads (Gilucis, 2007). Visual assessment of the territory pointed out several sources of possible heavy metal leaching from open iron-scrap stacks further to the soil and possibly to groundwater. Recommendations for the re-use of these slightly up to highly degraded areas usually include more detailed environmental pre-assessment in order to understand the severity of the problem and potential contamination level in groundwater. Soil sampling should not be the key method for detection of contamination and the necessity for remediation, because samples as the point sources of analyzed contamination can be misrepresenting the real situation. Groundwater sampling must be done in these areas in order to have more complete view on the size of the problem. Thus, monitoring results in former military area in 'Daugavgrīva' show exceeding heavy metal content in groundwater – every year Cu content in groundwater samples is slightly exceeding the critical boundary level, meaning that the source of contamination is soil (Burlakovs and Vircavs, 2011). This example was taken, because this area is on the list according to the Regulation of the Cabinet of Ministers Nr.483. Identification and Registration of Contaminated and Potentially Contaminated Sites as the 1st category polluted site (Piesārņoto un potenciāli piesārņoto vietu apzināšanas un reģistrācijas kārtība, 2001).

The List contains most of former USSR military territories as contaminated or potentially contaminated, because in past not much care was taken on hazardous residuals from military operations, iron-scrap, oil product refilling and loading etc. Therefore, former USSR military territories are one of most important sources of contamination; thus, many research works had been done since 1995 to prepare the information and proposals for remediation (Vēsturiski piesārņotu teritoriju sanācija. Nacionālā programma, 2006).

The 'Jaunais Mežaparks' area of 31.6 ha is not included in the list mentioned above, but there is still a great possibility that contamination with heavy metals and other pollutants is present in the area. Other contaminants such as oil products are very often found in former military areas. Those were visually detected and photographed in 'Jaunais Mežaparks'. Therefore, additional detailed research in the area is needed, in which contaminant sources, amount and flows would be determined. The applicability of remediation technology is dependent on site-specific conditions, type of contaminants and other factors. Also, excavation of contaminated soils can be applied, but only if these can be transported to hazardous waste landfill and if the amount is negligible; otherwise it is not acceptable.

The network of groundwater monitoring wells in surroundings must be developed, where regular monitoring of groundwater will be performed to control the contaminant flow / groundwater quality and flow direction in future. It is recommended to carry out a risk assessment based on a planned regular (2-4 times per year) groundwater monitoring data. In addition, groundwater quality in surroundings and planned residential and commercial building areas with random selection method should be regularly monitored. In the 4th sub-area, heavy metal remediation using appropriate remediation clean-up methods is recommended. It can be remediated using different methods, but one of the best examples is phytoremediation technology – with the use of plants to remove, destroy or sequester hazardous substances from the environment. After additional research different soil amendments also can be used; it can be a good approach for cationic metals if those are concentrated in the upper part of the soil; though these amendments must be chosen after deeper evaluation and chemical experiments.

Conclusions

Former military area 'Jaunais Mežaparks' has slightly higher ordinary metal and heavy metal contents in soil due to previous logistic and warehousing activities in the past. Point sources of heavy metal contamination possibly are leaching further to the groundwater. Visual assessment and photographic evidence provided material that area is possibly polluted also with oil products. The contamination is not very high like in areas of directly industrial soil as in most contaminated parts of Riga and Liepāja

harbors, but still is exceeding target values. Heavy metal content in soil can be additionally influenced by anthropogenic atmospheric loads.

The in situ and ex situ technologies can be used for remediation of contaminated sites. The future of military site remediation in Latvia after careful pre-assessment possibly could be done by stabilization / solidification, separation / concentration, chemical treatment, soil flushing, phytoremediation technologies or combination of several ones. The site 'Jaunais Mežaparks' is planned as an area of commercial and residential use in future; thus, careful environmental assessment should be done there, but the future use of 'Daugavgrīva' area is supposed to stay for industrial purposes as the port structure.

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References

1. Burlakovs J., Vircavs M. (2011) Possible Applications of Soil Remediation Technologies in Latvia. *RTU Zinātniskie Raksti*, 13. sēr., Vides un klimata tehnoloģijas. 7. sēj., pp. 46–53.
2. Critto A., Cantarella L., Carlon C., Giove S., Petrzzelli G., Marcomini A. (2006) Decision Support-Oriented Selection of Remediation Technologies to Rehabilitate Contaminated Sites. *Integrated Environmental Assessment and Management*, Vol. 2, No3, pp. 273–285.
3. Gilucis A. (2007) Mikro - un makroelementu satura un izplatības likumsakarības Latvijas augšņu virsējos horizontos (Relevancies of content and distribution of trace and major elements in the Latvian topsoils). Doctoral Thesis for Scientific Degree of Dr.geol. University of Latvia, Riga, 5–20. lpp. (in Latvian).
4. Liepājas ostas vides izpēte (Liepaja Navy Port Environmental Research) (1996) ES PHARE programme and the Government of Latvia. Report: Baltec Associates, Inc., 7–34. lpp. (in Latvian).
5. Map of Latvia (2012) Available at: www.latvijas-karte.zl.lv, 25 February 2012.
6. Vēsturiski piesārņotu teritoriju sanācija. Nacionālā programma. (National Programme of Remediation of Historically Polluted Sites). ERAF Project. (2006) Available at: http://www.vidm.gov.lv/lat/finansu_instrumenti/kohez/files/text/finansu_instrumenti/koh_f/nac_prog_2007_2013//NP_piesarnojums.pdf, 15 February 2012 (in Latvian).
7. Noteikumi par augsnes un grunts kvalitātes normatīviem. MK noteikumi Nr. 804. 1. Pielikums (Regulation of the Cabinet of Ministers No. 804. Instructions on Environmental Quality Standards for Soils. 1st Amendment) (2005) "LV", 172 (3330) Available at: http://www.likumi.lv/doc.php?id=120072, 15 February 2012 (in Latvian).
8. Piesārņoto un potenciāli piesārņoto vietu apzināšanas un reģistrācijas kārtība. MK noteikumi Nr. 483, I-VII daļa (Regulation of the Cabinet of Ministers No. 483. Identification and Registration of Contaminated and Potentially Contaminated Sites. Parts 1-VII). (2001) "LV", 171 (2558) Available at: http://www.likumi.lv/doc.php?id=55895, 15 February 2012 (in Latvian).
9. Piesārņoto un potenciāli piesārņoto vietu reģistrs. National Register of Contaminated and Potentially Contaminated Sites. (2001) LVĢMC. Available at: http://oas.vdc.lv:7779/p_ppv.html., 10 February 2012 (in Latvian).
10. Prokop G., Schamann M., Edelgaard I. (2000) Management of contaminated sites in Western Europe. Topic Report. No 13/1999. European Environment Agency, Copenhagen, pp. 17–32.
11. Rīgas attīstības plāns 2006-2018 (Riga City Development Plan 2006-2018) (2006) Available at: http://www.rdpad.lv/rpap/att_plans, 21 March 2012 (in Latvian).
12. Vircavs M. (2008) Sediment Quality Assessment in Latvia Water Bodies. Ecological Chemistry and Engineering, Vol. 15, No 8, pp. 831–839.

ASSESSMENT OF LANDSCAPE ECOLOGICAL AESTHETICS IN URBAN AREAS. EXAMPLE OF JELGAVA

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Abstract
Nowadays, linkage of landscape ecology with landscape aesthetics becomes very topical, especially when people move from rural areas to big towns and cities. Landscape ecological planning becomes more important in terms of sustainable environment. Landscape assessment and investigation needs a multidisciplinary approach. The aim of the study was to evaluate landscape ecological aesthetics in urban area. The selected city for study was Jelgava – city with a special characteristic landscape of Zemgale plains and wide green spaces in the city centre. Jelgava is one of the examples of complex urban system with ecological environment. This research presents landscape evaluation of Jelgava using ecological aesthetics assessment method. Territory of Jelgava was divided in groups of research areas: green spaces, residential areas and other territories. Qualitative and quantitative methods were used in the research. The methods applied in this research describe the present situation of the city. Landscape inventory, biotope structure analysis and evaluation of landscape ecological aesthetical qualities give a general overview of the problems and opportunities of the examined city. Research study was managed in autumn and winter 2011. The results show the need for sorting the cityscape and use of ecological principles in further urban planning. Green areas of Jelgava are ecological and aesthetical valuable but multi-storey residential areas have low quality of landscape ecological aesthetics.
Key words: landscape structure, ecological and aesthetical quality, urban planning, city of Jelgava.

Introduction

The proportion of urban green areas is declining over the time, therefore, there is a need for preservation of existing green wedges and construction of new ecosystems that would connect existing sites. Growing level of urbanization in cities and large towns converts native ecosystems to agricultural lands or urban living spaces (Lovell and Johnston, 2009). Urban landscapes are systems where natural and social processes together shape the ecosystems. The urban landscape is very complicated with residential, commercial, industrial, government-institutional, cultural-educational land uses, areas of remnant vegetation, secondary green areas such as parks, gardens or cemeteries and other land uses (Andersson, 2006). Urban landscapes have many functions: food production, industrial use, recreation, housing, water extraction, nature conservation and global environmental control (Vos and Meekes, 1999). Green urban network will help to maintain biological diversity and attract wildlife between all of these types of urban areas. Green spaces in the city are mainly semi-natural areas, managed parks and gardens, supplemented by scattered vegetation and divided by roads (Jim and Chen, 2003). Green areas have to be multifunctional with recreational function, aesthetical duty and environmental benefit.

The research on interaction of landscape ecology and aesthetic becomes more actual in terms of sustainable landscape planning in urban areas. Urban landscape is studied as a complex system in which there are problems with its interpretation in human perception and necessity of use of sustainable principles (Nassaurer, 1995; Vos and Meekes, 1999; Lovell and Johnston, 2009). Landscape 'ecological aesthetics' own idea of making natural processes visible through design (Olin, 1988). This aspect is wide discussed in studies of forest landscape and management (Gobster, 1999). There have been few researches of landscape ecological aesthetics on Latvian landscape (Ziemeļniece, 1998; Zigmunde, 2010).

Selected city for study was Latvian city with fourth largest number of population. Jelgava is located in southern part of Zemgale plain. At the same time it is considered as one of the greenest cities in Latvia. There are two different objects in the centre of town: the Jelgava Palace and the territory of Natura 2000 – an important place of bird nesting and the pasture. There are flood-land meadows and habitat for wild horses.

Many of development priorities of Jelgava are associated with improvement of environmental quality. The challenges for development vision of Jelgava are to improve urban green spaces, to conserve biodiversity, forest habitats and protected natural assets and to build qualitative living environment and the individual high-rise residential neighbourhoods in Jelgava area (Jelgavas pilsētas ilgtermiņa..., 2007).

The main purpose of the study was to evaluate urban landscape of Jelgava city using ecological aesthetics assessment method and to define difficulties of further sustainable development. In order to achieve it, the following objectives were defined:

- to manage landscape inventory of current situation in Jelgava using photo fixation,

accounting and characterizing of landscape elements;
- to evaluate biotope structure and vegetation in blue-green areas of Jelgava city;
- to assess landscape ecological aesthetics using comparative matrix and to detect main problems to challenged landscape for further development.

Based on the research results, possible development of landscape ecological aesthetics of Jelgava will be carried out in further studies. Research helps to understand and analyze successful development directions for Jelgava city.

Materials and Methods

The basis of the research was Jelgava city. Landscape survey, photo fixation and inventory were managed in the spot of this Latvian city.

Jelgava is a city in central Latvia about 41 km southwest of Riga. As of 1st of January 2011, the city had a population of 64516 inhabitants. Jelgava is situated on both banks of the Lielupe River from 0.0 to 6.0 m above sea level. Total area of Jelgava is 60 km^2, of which open-water area is 2.34 km^2 and parks cover 1.62 km^2 of Jelgava area (Jelgavas pilsētas pašvaldības..., 2012). It is the largest town in Zemgale region. Jelgava has regular, broad streets.

In the research, general scientific qualitative research methods were used. The subject of research was ecological aesthetical quality of green environment in urban territories.

Landscape inventory was used to survey current situation of Jelgava. Inventory was conducted within the description of the landscape the collection, recording and landscape assessment adding value to individual landscape elements, depending on the specific criteria (Ainavu aizsardzība..., 2000). At the beginning of inventory of the landscape, it was necessary to study the existing situation of Jelgava. Photo fixation was carried out during the research in autumn and winter 2011. The weather was cloudy and dull. The analyzed areas were grouped by its functional use: neighbourhood areas, courtyards of multi-storey buildings (Figure 1), urban natural areas, parks, forest areas, water courses and reservoirs (Figure 2). There was existing landscape visual and ecological structure marked on inventory map.

The value of landscape is expressed by specific land uses, field patterns, traditional architecture (Krause, 2001). Aesthetical quality of Jelgava landscape was mapped using visual landscape assessment method. Landscape scenery, significant viewpoints and elements were marked in an assessment map. The aims of visual quality assessment are to help to list the areas to be protected, to determine whether a landscape is aesthetically appropriate or not and to define physical landscape components that affect the preferences for this particular area (Kane, 1981; Bulut and Yilmaz, 2008). Cartographic method 'City building analysis' which is developed by Kevin Lynch was used for distribution of city regions with similar properties (Lynch, 1960). There were housing areas, commercial and industrial territories, manufacturing areas and green spaces detected in Jelgava city.

Biotope analysis is an ecological characterisation of landscape structure of urban areas. In these maps, the word 'biotope' is synonymous to word 'habitat', it is defined as area in which animals and plants can live, and primarily represents different land-use classes (Leitão and Ahern, 2002; Löfvenhaft et al.,

Table 1

Landscape ecological aesthetics assessment matrix of territories in Jelgava

Values	Area 1	Area 2	Approach
Order, regularity	1-10	1-10	Aesthetics
Quality of man-made elements	1-10	1-10	
Visible human intention	1-10	1-10	
Particularity	1-10	1-10	
Use of outlandish species	1-10	1-10	
Use of natural forms	1-10	1-10	
Accordance with architecture	1-10	1-10	
Biodiversity	1-10	1-10	Ecology
Accordance with landscape type	1-10	1-10	
Native species	1-10	1-10	
Natural elements	1-10	1-10	
Carelessness	1-10	1-10	
Wildlife	1-10	1-10	
Unaffected nature processes	1-10	1-10	

Source: author's created.

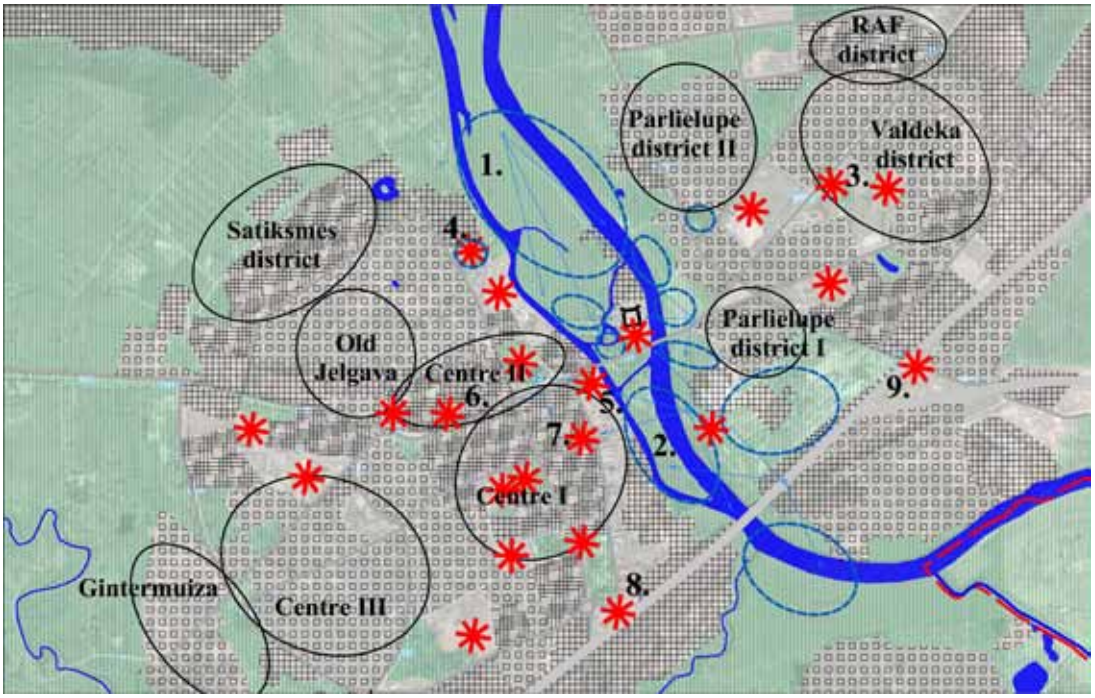

Figure 1. Results of Jelgava building structure and scenery analysis:
small residential areas; multi-storey residential areas; industrial and technical areas; green areas; important public object; open area; significant viewpoint; 1. Pils Island; 2. Pasta Island; 3. Valdeka Palace; 4. Villa Medem; 5. Tower of St. Trinity Church; 6. St. Anna Church; 7. St. Rome Catholic Church; 8. Railway Station 'Jelgava'; 9. Railway Station 'Cukurfabrika'.
Source: author's created on Google Maps satellite.

2002). Biotope structure analysis was used to evaluate landscape ecological system in Jelgava. Cartographic material of Jelgava area was classified by land use and vegetation type using aerial photographs. Vegetation type was also defined by obtained data of the landscape inventory.

Variety of ecologically valuable habitats in urban areas where there are rare species or that have importance in maintaining biodiversity were marked in maps with colours and symbols, for example: broad-leaved forests; the territory of old trees; an open meadow; marsh areas; river, lake, pond area; fallen tree stumps and developed land. The category 'developed land' is used for those parts of the built-up areas that have no or have scattered (0-10% of the total area), sparse (10-30%) or dense (30-50%) vegetation cover, including small valuable biotopes – linear or point elements (Löfvenhaft et al., 2002).

Landscape ecological aesthetics assessment method (Table 1) was used to compare different values of various areas of Jelgava (private residential areas, multi-storey residential areas, public parks, nature pavement territories, etc.). It is possible to classify evaluated landscapes by their acquired ecological aesthetics, if data are inserted into assessment matrix (Jankevica, 2012).

Challenged landscapes were evaluated using criteria of landscape ecology and aesthetics, according to a 1-10 score system: 1 point for low quality, 10 points to highest quality. Landscapes were divided in four groups: 1) with low quality of aesthetics and ecology; 2) with high quality of ecology, low quality of aesthetics; 3) with low quality of ecology, high quality of aesthetics; 4) with high quality of landscape ecology and aesthetics.

Results and Discussion

According to landscape inventory, Jelgava has a relatively green structure of urban environment. Jelgava has a large variety of green areas (Figure 1). There are natural areas, for example, flood-land meadows, islands, watercourses and man-made areas such as squares and residential areas in the centre of the city. Jelgava has a high aesthetical potential although there is a large amount of Soviet period architecture heritage and lack of maintained historical environment. There are many public parks and green areas in Jelgava.

There are two islands between the rivers: Pils Island in the North and Pasta Island in the South of the city. Jelgava is a city of dynamical open or linear designing structure, where industrial and residential

areas are located next to green territories. Expansion of Jelgava is limited by river shores. The building structure of town is influenced by natural plain topography and watercourses.

Small residential areas dominate in building structure of Jelgava, although there are many multi-storey building areas on the left side of the city. The most of multi-storey residential areas were built over the period of second half of 20th century. Multi-storey residential areas are concentrated in large massifs with free planning principles that were applied in the building location processes (Īle, 2011a). According to the recent studies of other authors, courtyards in these regions have spatial landscape composition problems and lack of ecological valuable environment (Īle, 2011b). There are problems with parking lots, lack of greenery and unarranged children playgrounds in these courtyards. Industrial areas and stores, as well as technical services are located along main roads, rivers and railway outside city centre. Manufacturing areas are located on the right side of Jelgava. Jelgava has a low silhouette with few particular pikes of churches and vast multi-storey building areas in some places.

Concept of site's landscape ecology has to be in harmony with visual information of space, especially appreciated is location of main sights and viewpoints. Significant viewpoints are located next to Pils Island and flood-plain grasslands. There are many open spaces with long-range distant views. The bridge offers a wide significant view of the Jelgava Palace. Silhouette of the town is typical from the right river bank over the Pasta Island. Significant architectural and functional objects are located on the left side of the Lielupe River. There are churches, Villa Medem, tower of Saint Trinity Church and educational buildings in the centre of Jelgava. Most attractive object on the right side of the city is Valdeka Palace. Landscape aesthetical quality is reduced by unattractive multi-storey courtyard areas, industrial areas and abandoned sites, for example, area of former sugar-refinery.

Example of Jelgava shows ecologically valuable biotopes in the centre of the city (Figure 2). There are grasslands, wood and swamp as important biotopes in the centre of Jelgava. There is a developed land with dense or no vegetation covers next to biotopes. Small rivers Platone, Vircava and Svete are located outside the city centre.

Area of Langervalde wood bounds the centre of Jelgava from periphery. Core area with significant ecological values is Pils Island central area, connectivity zones are river shores, swamp and park near Jelgava Palace. Buffer zones surround the core

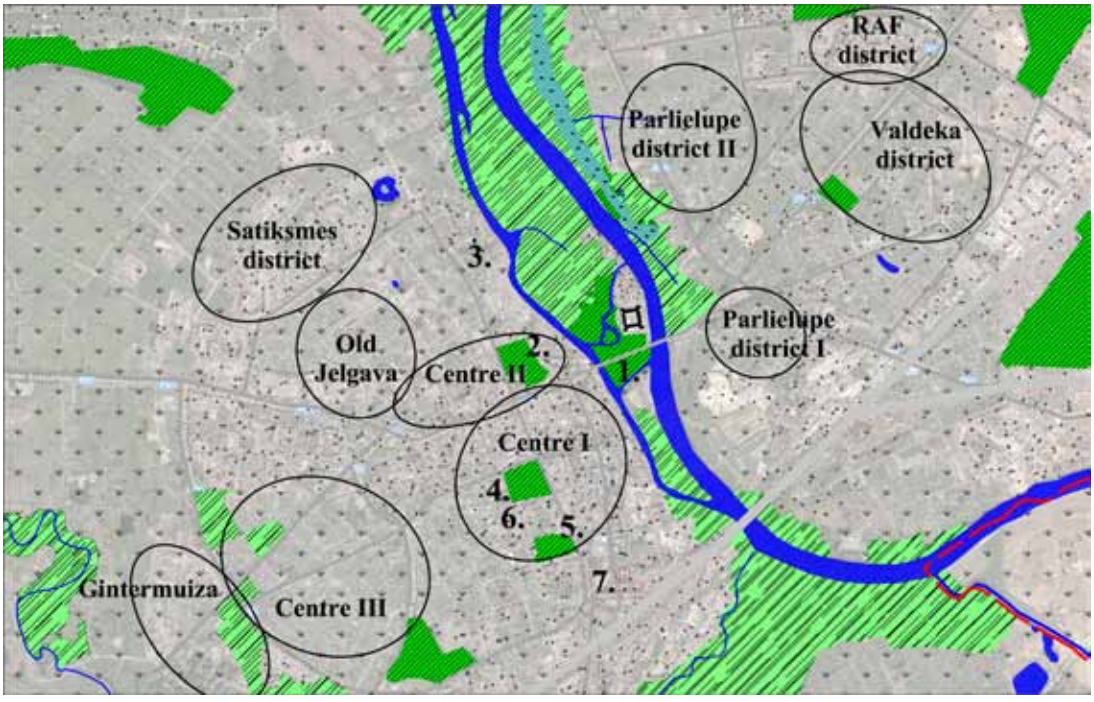

Figure 2. Fragment of Jelgava Biotope map.

forest with old-growth trees; grasslands and meadows; swamp; water; developed land with dense vegetation cover; developed land without/with sparse vegetation cover; 1. Park of Jelgava Palace; 2. Central square; 3. Uzvaras Park; 4. Raina Park; 5. Alunana Park; 6. Square of Valnu Street; 7. Stacijas Park. Source: author's created on Google Maps satellite.

and connectivity zones, for example, small private residential areas. Green development areas with a high ecological potential are within core areas. These are flood-plain meadows on Pils Island. Wild tulips *(Tulipa sylvestris)* are found in meadows of Pils Island, which makes this place significant for inhabitants of Jelgava.

Public green spaces offer excellent design opportunities for ecological challenge. The old park of Jelgava Palace is full of ancient trees: oaks *(Quercus)*, limes *(Tilia)*, elms *(Ulmus)*, maples *(Acer)*, ash *(Fraxinus)*, horse-chestnuts *(Aesculus)* and willows (*Salix)*. There are four secular trees. Similar species of trees encounter in the rest of Jelgava parks. Many of these parks have to be improved and greeneries should be arranged. There are annual and perennial flowers planted in Raina Park, Stacijas Park and Square of Valnu Street. Man-made green areas are constructed according to plain Zemgale landscape type.

Jelgava has wide streets compared to other Latvian cities. Street greenery is shaped where the road is wider. Most popular tree species used as street greenery are common lime *(Tilia vulgaris)*, rowan *(Sorbus aucuparia, Sorbus intermedia*) and different varieties of maples *(Acer)*. Greenery system of Jelgava is relatively appropriate, though the system of biocorridors does not run effectively.

Small private gardens occupy the largest part of Jelgava urban areas. There are vegetation and habitats for wildlife in these gardens but the ecological quality can be improved. Residential yards ordinarily include mowed lawns, hard groundcover, ornamental flower beds, trees and outdoor recreation facilities. There is a lack of native vegetation and less ecological diversity in new small private garden areas compared to old ones. The option of small gardens to use ecological functions depends on their composition and configuration, as well as their size. Usage of indigenous species and natural forms of plants increases ecological and also aesthetical quality of garden landscape.

Multi-storey residential areas, and industrial and technical areas have problems with lack of vegetation and fragmentised natural areas and biotopes. Greenery of multi-storey courtyards is not shaped in different levels. There is a lack of shrubs, vines and flowers in almost all courtyards.

The evaluated landscapes of Jelgava were classified by their acquired ecological aesthetics (Table 2).

Assessment of parks and public spaces shows that Uzvaras Park and Square of Valnu Street have the highest aesthetical values. These are territories which are recently improved and facilitated with new components. Park of Jelgava Palace, Alunana Park and Stacijas Park got the highest ecological values. There are many old trees, scenic landscape design and natural appearance in these parks. However, ecological quality of other parks has to be improved.

Table 2

Evaluation of areas in Jelgava

Types of urban landscape	Analyzed areas	Score Aesthetics/ Ecology
Public parks, squares	Park of Jelgava Palace	7.9/6.0
	Park of Central square	7.0/5.7
	Uzvaras Park	8.1/5.0
	Raina Park	7.3/5.4
	Alunana Park	6.6/6.1
	Stacijas Park	7.3/6.1
	Promenade of Lielupe	8.1/5.4
	Square of Valnu Street	8.3/5.1
Small residential areas	Old Jelgava	8.0/7.0
	Centre III	7.8/6.3
	Gintermuiza	7.8/5.9
	Parlielupe I	7.8/6.2
	Parlielupe II	7.8/6.6
	Valdeka district	8.0/6.9
Multi-storey residential areas	Satiksmes district	5.3/4.4
	RAF district	5.1/4.4
	Centre I	4.4/4.2
	Centre II	4.4/4.0
Other areas	Pasta Island	6.1/7.6
	Pils Island	7.0/9.6
	Former sugar-refinery	3.0/7.3
	Langervalde wood	6.7/9.6

Source: author's created.

Evaluation of small residential areas shows that districts of old houses with varied gardens of different plants (trees, bushes, flowers) have higher ecological quality. Districts of new housing areas have less greenery, only mown lawn and rows of coniferous trees that decrease biodiversity and use of native species and wildlife. Location of the districts also affects ecological values. If a district is far from main roads and traffic, ecological quality of gardens increases.

There are differences between various multi-storey residential areas in terms of aesthetical value score. There have been recent improvements of courtyards in Satiksmes and RAF districts. Recreation and children playground zones are arranged and advanced but the problem of lack of greeneries still exists.

Areas with the highest score of ecology are Pils Island and Langervalde wood nature pavement territories with unaffected nature processes. Assessment score for aesthetic and ecological values of Pasta Island will change after the ongoing

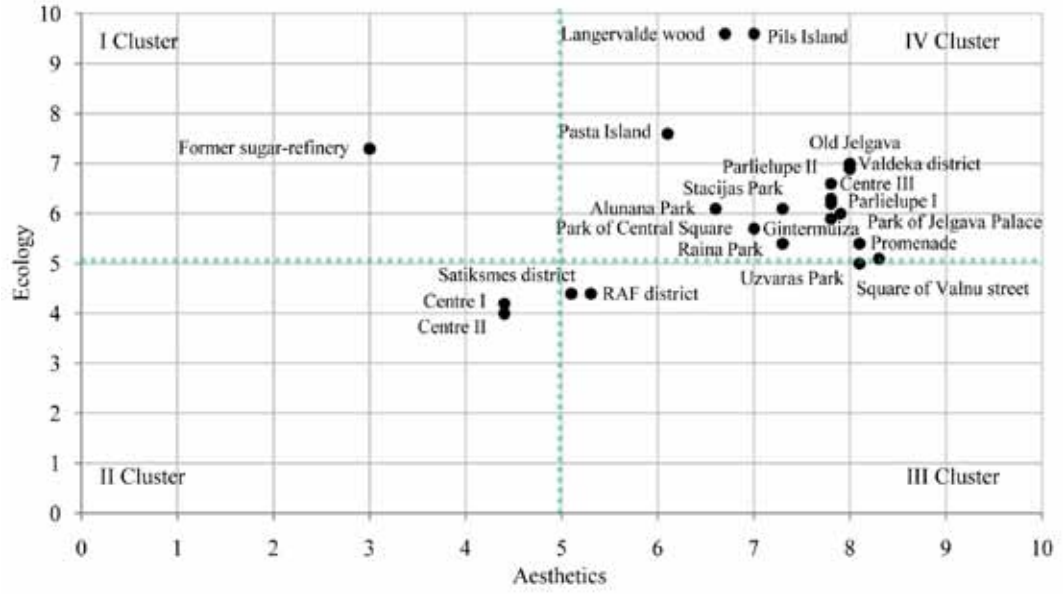

Figure 3. Graphical connection between ecology and aesthetics of Jelgava area.
Source: author's created.

construction operations. Existing nature pavement territory will become a recreation area with sports places, children playground and new buildings.

Evaluated areas were divided in four clusters by landscape ecological aesthetics (Figure 3). There are only one territory – former sugar-refinery – with high ecological quality and low aesthetical quality in the first cluster. Areas with low quality of ecology and aesthetics are courtyards of multi-storey residential areas in the centre of Jelgava. Areas with low ecological quality and high aesthetical quality are multi-storey residential areas and Uzvaras Park. Majority of areas of Jelgava are located in the fourth cluster with high level of both values. Areas with high aesthetical values are parks and gardens of small private residential areas.

This landscape assessment portrays subjective opinion. The obtained score will be plausible if this assessment matrix is filled in by several experts from different science disciplines (architecture and ecology). Research for output of criteria for this assessment matrix will be continued. There will be limitations for scores (for example, biodiversity, regularity, wildlife) created.

Conclusions

1. The green structure of Jelgava is formed by untouched nature pavement territories, woods, parks and public spaces, watercourses and small private residential areas with cultivated gardens. Small residential areas dominate in building structure of Jelgava. There is a traditional gardening used instead of ecological gardening in private residential areas of Jelgava.
2. There are ecologically valuable biotopes in the centre of Jelgava next to Lielupe River. There should be sustainable structures in the public parks of Jelgava. Greenery system of Jelgava, including green spaces and street greenery, has to be arranged to create biocorridors for wildlife.
3. Assessment of landscape ecological aesthetics shows that territories with high ecological quality are woodlands, meadows and swamps. Public parks and small gardens are landscapes with highest aesthetical quality in Jelgava. Nature pavement territories have high quality in both categories. Landscape ecological and aesthetical quality of multi-storey residential areas has to be improved. Industrial areas and abandoned sites have low ecological and low aesthetical quality.
4. Development of the city landscape is influenced by esthetical resources and use of ecological principles. Jelgava has high potential for ecological planning due to wide nature pavement areas and broad streets. The aesthetical quality of Jelgava city has to be improved by restoring significant objects, public spaces and living areas.
5. The objective of the research has been achieved based on managed landscape ecological aesthetics assessment of urban areas in Jelgava. This test version will be upgraded with criteria for selection possibilities of scores of each landscape value.

References

1. *Ainavu aizsardzība* (Landscape protection) (2000) Vides aizsardzības un reģionālās attīstības ministrija, Rīga, 84 lpp. (in Latvian).
2. Andersson E. (2006) Urban Landscapes and Sustainable Cities. *Ecology and Society*, 11, pp. 34–40.
3. Bulut Z., Yilmaz H. (2008) Determination of landscape beauties through visual quality assessment method: a case study for Kemaliye. *Environment, Monitoring, Assessment*, 141, pp. 121–129.
4. Gobster P.H. (1999) An ecological aesthetic for Forest Landscape Management. *Landscape Journal*, 18, pp. 54–64.
5. Īle U. (2011a) *Dzīvojamo rajonu iekškvartālu ainaviskā kvalitāte Latvijas pilsētās.* (The landscape quality of the residential area courtyards in the cities of Latvia). Summary of PhD thesis, Latvijas Lauksaimniecības universitāte, Jelgava, 72 lpp. (in Latvian).
6. Īle U. (2011b) Landscape composition development stages in multi-storey residential areas of the Baltic sea reagion. *Science – Future of Lithuania, K. Šešelgis' Readings - 2011*, Vilnius Gediminis Technical University, pp. 16–22.
7. Jankevica M. (2012) Comparative analysis of methodologies for landscape ecological aesthetics in urban planning. *Science – Future of Lithuania, K. Šešelgis' Readings - 2012*, Vilnius Gediminis Technical University, pp. 113–119.
8. *Jelgavas pilsētas ilgtermiņa attīstības stratēģija 2007.-2020. gadam* (Jelgava city long-term development strategy for year 2007-2020) (2007) Jelgavas pašvaldība, 7 lpp. (in Latvian).
9. Jelgavas pilsētas pašvaldība (2012) Available at: http://www.jelgava.lv/the-city/jelgava-in-short/, 12 February 2012.
10. Jim C.Y., Chen S.S. (2003) Comprehensive greenspace planning based on landscape ecology principles in compact Nanjing city, China. *Landscape and Urban Planning*, 65, pp. 95–116.
11. Kane P.S. (1981) Assessing landscape attractiveness: A comparative test of two new method. *Applied Geography*, 1, pp. 77–96.
12. Krause C.L. (2001) Our visual landscape Managing the landscape under special consideration of visual aspects. *Landscape and Urban Planning*, 54, pp. 239–254.
13. Leitão A.B., Ahern J. (2002) Applying landscape ecological concepts and metrics in sustainable landscape planning. *Landscape and Urban Planning*, 59, pp. 65–93.
14. Lovell S.T., Johnston D.M. (2009) Designing Landscapes for Performance Based on Emerging Principles in Landscape Ecology. Available at: http://www.ecologyandsociety.org/vol14/iss1/art44/, 14 January 2012.
15. Löfvenhaft K., Björn C., Ihse M. (2002) Biotope patterns in urban areas: a conceptual model integrating biodiversity issues in spatial planning. *Landscape and Urban Planning*, 58, pp. 223–240.
16. Lynch K. (1960) *Image of the city*. MIT Press, Cambridge, UK, 194 p.
17. Nassaurer J.I. (1995) Messy ecosystems, orderly frames. In: Swaffield S. (eds) *Theory in Landscape Architecture*, University of Pennsylvania Press, Philadelphia, USA, pp. 196–206.
18. Olin L. (1988) Form, meaning, and expression in landscape architecture. *Landscape Journal*, 7, pp. 149–168.
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.
20. Ziemeļniece A. (1998) *Estētiskā kvalitāte ainaviskajā telpā.* (Aesthetic quality of picturesque area). Latvijas Lauksaimniecības universitāte, Jelgava, 98 lpp. (in Latvian).
21. Zigmunde D. (2010) *Latvijas urbānās un lauku ainavas estētiskā un ekoloģiskā mijiedarbe.* (The aesthetic and ecological interaction of the urban and rural landscape). Summary of PhD thesis, Latvijas Lauksaimniecības universitāte, Jelgava, 83 lpp. (in Latvian).

PUBLIC PERCEPTION ABOUT LANDSCAPES OF WATERMILLS AND SMALL-SCALE HYDROELECTRIC POWER PLANTS IN LATVIA

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Abstract
The landscape in Latvia is managed and planned in different levels and regulations. The survey has been undertaken in Latvia with the aim to assess the landscape as regards the aesthetical quality assessment in Latvian watermills and small-scale hydroelectric power plant territories by means of public perception. Duration of research was from May 2011 till March 2012. The method used in this survey is the public questionnaire method. Public notions concerning researched landscapes territories in Latvia reveal that the landscapes in these territories are mainly assessed critically; however, in the assessment of visual information from pictures taken in particular territories the results are different, and the value of these territories is mainly assessed positively. The contribution of Latvian people's knowledge regarding improvement in the landscapes situations in researched territories of Latvia has to be realized.
Key words: landscape perception, public perception assessment, questionnaires.

Introduction

The process of investigation of landscape is a complex process. Several surveys have been done in an attempt to research public perception till now but no one of them has been able to display the perception of landscape in watermills and small-scale hydroelectric power plants (HPP) territories. From ancient times, watermills are regarded as one of the most fundamentally required essentials of life. The existing situation got mightily affected from the beginning of events in the period of World War II. These processes progressed until the independence of Latvia in 1991, when the ownership of private land was reverted to proprietors. The landscape of watermills, small-scale HPPs, and imaginary landscape of these territories have led to building up of established notions in human minds. These notions could have further influenced the management of landscape in different levels of the landscape planning system. But, these notions have not been researched yet. The several researches that have been done related to the territories in Latvia stem out of a mental perception point of view of the Latvian landscape. Countryside is perceived as an important aspect of Latvia and a contributor to a sense of identity for the local population (Bell, 2007), the historical investigation of watermills in Latvia (Teivens, 1985) rather literary than scientifically has reflected the individual perception and daily work by A. Zemdega (2004).

In the European Landscape Convention, the landscape is defined 'area, as perceived by people (…)' (European Landscape Convention, 2000), which means that it is the territory which has to be perceived. The insight of landscape causes the quality of perceived information. 'Landscape protection, management, and planning hence concern the characteristics of the landscape that the involved population wishes to give recognition to in their surroundings' (Jones and Stenseke, 2011). The methods of public perception assessment are supported by position, where is said that the best data source for landscape quality assessment is the general public, and that the visual attractiveness of landscape after all is individual persons focussed information of summarised experience result in a landscape (Briggs and France, 1980). Visual landscape quality is nominated as observer's individual basis of perception for all of the landscape, and as often as not is used in a questionnaire, and verbal surveys (Arthur et al., 1977). Depending on that, it is necessary to survey the comprehension and assessment of landscape in society. The aim of the research was to collect information by means of public perception regarding the landscape aesthetic quality assessment in Latvian watermills and small-scale HPP territories. The method used is the public questionnaire method. The results will make it possible and could be used to make further decisions regarding landscape politics.

Materials and Methods

The territories of survey are the watermill territories, which ware marked in a maps of 1920ties, and the small-scale HPP, marked in a map of MHEA (Association of small-scale Hydroenergy) plan (Siļķe, 2008). After the theoretical survey data, these territories are classified by the existing general function of main building – 1) The main building of watermill is gone; 2) Main building of watermill is abandoned, or is in ruins; 3) Main building of watermill does exist and is in use; 4) Newly constructed building with small-scale HPP function. Several territories showing one type of buildings were chosen and were inspected. In Latvia according to the maps of 1920ties there were more than 450 watermills territories. At present are more than 150 small-scale HPP, several of which involves the old watermills with new functions of producing. Three areas in Latvia are with high density of build-up territories for watermills – Latgale, Vidzeme, and Kurzeme uplands areas.

For public perception of landscape assessment survey, the methods of questionnaires are applied, individually developed methods as Q-Sort method (Stephenson, 1953), Scenic beauty estimation method (Daniel et al., 1976)**.** For both of the mentioned methods here individually strengths and weakness are tested in several researches (Pidža, 2011; Fairweather and Swaffield, 2004; Pitt and Sube, 1979). The method used in this survey is the public questionnaire method. The questions were in closed form, with given answers constructed by the author. In the research three landscape assessment questionnaires were made use of, out of which in this survey of the public perception of landscape, the aesthetical assessment is displayed. Duration of research was from May 2011 till March 2012. Specified territories of watermills and small-scale HPP were chosen near and inside in to Latgale upland area. **Questionnaire No. 1** addresses the aim to summarize information from local people living near researched territories. Data was collected by making field trips to these territories. Questionnaire No. 1 was carried out in Prezma, Grienvalde, Erberge, and Peleci watermill or small-scale HPP. **Questionnaire No. 2** tackles the aim to collect information from people who are living in Latvia. Data was collected with internet system resources. **Questionnaire No. 3** deals with the aim to summarize information from inhabitants living in Latvia whose professions are or are not related to art, and inhabitants living abroad whose professions are related to art. The information was collected with internet systems resources where the questionnaires were published and anyone could to fill in the form of questionnaire. The pictures taken in territories of watermills and small-scale HPP were given for assessment.

Results and Discussion

The quantitative results of questionnaires were calculated and total numbers of answers were converted to percent. The data of percentage values was summarized in each question.

Characterisations of respondents

Questionnaire No. 1 – responses in total 9. Age: 2 persons were older than 80, 2 persons - 60-79 and 5 persons - 20-59. Questionnaire No. 2 – responses in total 113. Age: younger than 21 - answers from 10 persons, and in age group 22-59 - answers from 103 respondents. Comparison by means of being related to residence area: Riga - 26%, other cities - 8%, Kurzeme region - 12%, Zemgale region - 16%, Vidzeme region - 31%, Latgale region - 10%. Persons living near watermills and small-scale HPP 44. Questionnaire No. 3 – responses in total 209. Age: younger than 21 - 14 persons, 22-55 years - 189 persons, and 56 and older were 6 persons. Residence area: Riga 19%, other cities in Latvia - 33%, countryside of Latvia - 15%, abroad - 33% of the respondents (France, Germany, Serbia, Indonesia, Estonia, Sweden, Greece, Romania, UK, Hungary, Austria, USA, Belgium, Finland, Uruguay, Norway, Serbia, Turkey, Saudi Arabia, Slovenia, Cyprus, Ireland, Luxembourg, Italy). By profession, 48% of the respondents were related to art.

Public notions

'Measuring perception' is difficult, and this process involves many critical assumptions, investigating social perception means establishing the public significance of various landscape values (Cassatella, 2011). The values of landscape shapes are developed from knowledge, based on information regarding each territory and created in view of several notions and memories. In the research of public opinion, 'Generally people express at the same time both what the landscape is and what it should be. Hence, it is not easy to place a clear boundary between a purely descriptive and a purely analytical document' (Michelin et al., 2011). Notion of landscape in watermills and small-scale HPP was brought to light from information of data from Questionnaire No. 2. The questions were incorporated with the aim to assess the landscape according to the criteria which was given (Figure 1). Landscapes in watermills were assessed at a much higher value than in territories of small-scale HPP. In researched territories one of the main landscape perceptions which subordinates other elements is the architectural structure, the question of assessment of the architecture in these territories was given (Figure 2). Results reflect that approximately half of total responses hold a view that the materials used in buildings and wellhead equipment are incompatible with nature. Negative assessment is more complementary in case of small-scale HPP territories.

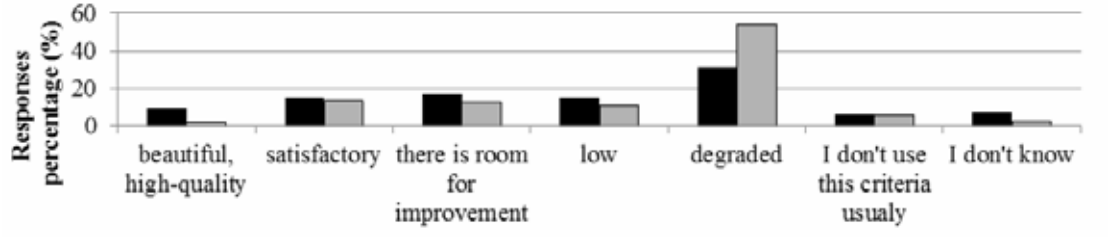

Figure 1. Landscape Assessment (Data from questionnaire No 2): ■ in watermills, ■ in small-scale HPP.

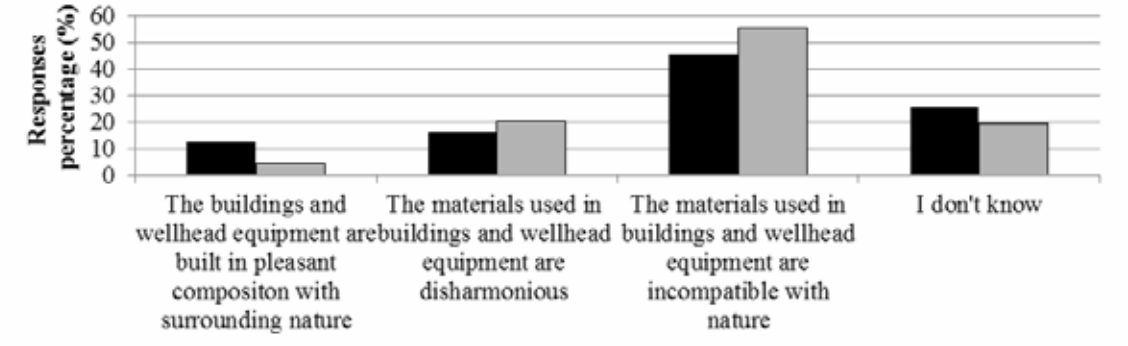

Figure 2. Buildings and wellhead equipment assessment in comparison with surrounding nature (Data from questionnaire No 2): ■ in watermills, ■ in small-scale HPP.

Visual landscape assessment

'While Public Preference methods can provide significant information about what elements of the landscape people find most visually pleasing or what management alternative is preferred, experts or professionals rather than the general public often make decisions involving visual impacts' (Kaplan, 1979). However, 'some also believe that the public lacks the experience and knowledge that is needed to be fully sensitive to aesthetic quality' (Carlson, 1986). With assumption that the society could appraise the situation based on visual information given, Questionnaire No. 3 was developed. For the landscape assessment of territories, results of this questionnaire are reflected in this survey. Coloured images in sizes of at least 6 cm high and with different widths were offered to respondents.

Balda watermill (Figure 3) is the territory where the main building of watermill does exist and is in use. The results were compared between the general public of Latvian inhabitants, Latvian inhabitants with profession related to art, and those from abroad related to art (Figure 4). In assessment of Figure 3, the vast majority of responses in all groups of respondents valuate the Balda watermill territory as beautiful. Most answers with '+3 very beautiful' and '+2 beautiful enough' values were given by the group of inhabitants related to art and living abroad. In assessment of landscape parameters which are the most visually pleasant the most responses were given to 'the emotional impression of this image' parameter (Figure 11). Plants as beautiful constituents were marked often by foreign specialists living abroad.

As the territory of newly constructed building with small-scale HPP function, the landscape in Galvani was assessed. A picture was taken with a view over the water reservoir next to the dam (Figure 5). In assessment of Figure 5, the most of responses valuate

Figure 3. Balda watermill (author L.Lazdāne, 2011).

Figure 4. Aesthetic assessment of Balda watermill: - - - - Latvian/general public, · · · · · · Latvian/related to art, ——— abroad/related to art.

Figure 5. Galvani small-scale HPP (author L.Lazdāne, 2011).

Figure 6. Aesthetic assessment of Galvani small-scale HPP: - - - - Latvian/general public, · · · · · · Latvian/related to art, ——— abroad/related to art.

particular territory as beautiful, respondents from abroad related to art gave more responses with positive assessment (Figure 6). In assessment of landscape parameters (Figure 11), all groups of respondents the most responses were given to 'the presence of water' parameter. Local respondent groups and respondents living abroad had different points of view about the parameters 'plants' and 'common situation in the picture'.

As a territory where the main building of watermill is gone, the landscape in Sankali watermill/small-scale HPP was assessed (Figure 7). The highest value for this territory with assessment marked '+3 very beautiful' was provided by the abroad-living respondents related to art (Figure 8). In assessment of landscape parameters (Figure 11), all groups of respondents the most responses were given to 'the presence of water' parameter. Local respondent groups and respondents living abroad had different points of view about the parameters 'plants' and 'common situation in the picture' (Figure 11).

As a territory where the main building of watermill is abandoned, or is in ruins, the landscape in Krievciems watermill/small-scale HPP was assessed (Figure 9). Overall, the landscape was assessed as beautiful, but there were differences in percentage

Figure 7. Sankali watermill/small-scale HPP (author L.Lazdāne, 2011).

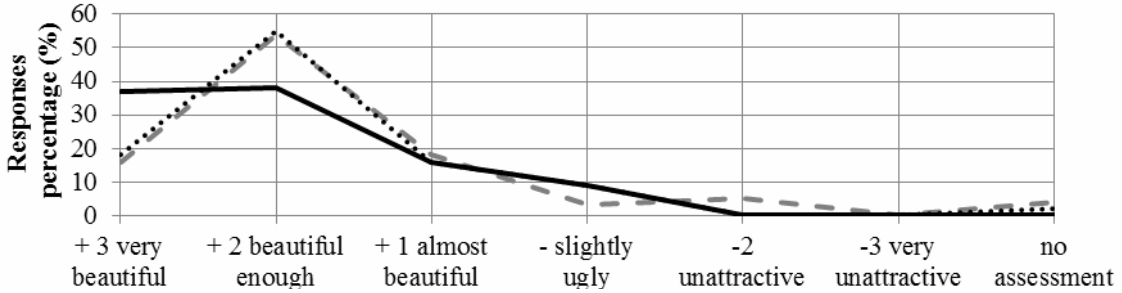

Figure 8. Aesthetic assessment of Sankali watermill/small-scale HPP: - - - - Latvian/general public, · · · · · · Latvian/related to art, ——— abroad/related to art.

Figure 9. Krievciems watermill/ small-scale HPP (author L.Lazdāne, 2011).

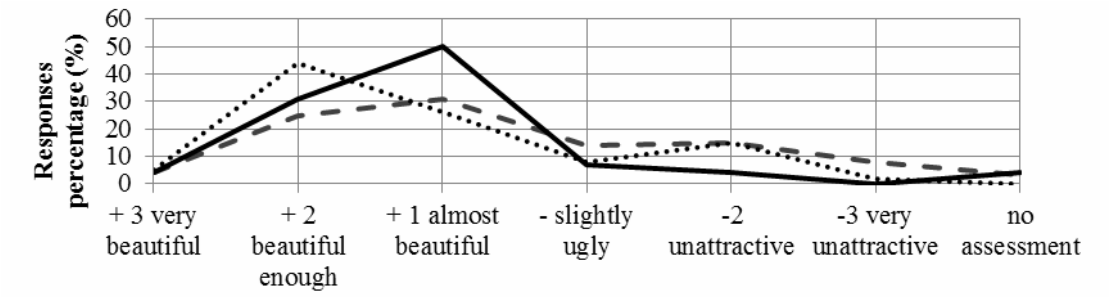

Figure 10. Aesthetic assessment of Krievciems watermill/small-scale HPP: - - - - Latvian/general public, · · · · · · Latvian/related to art, ——— abroad/related to art.

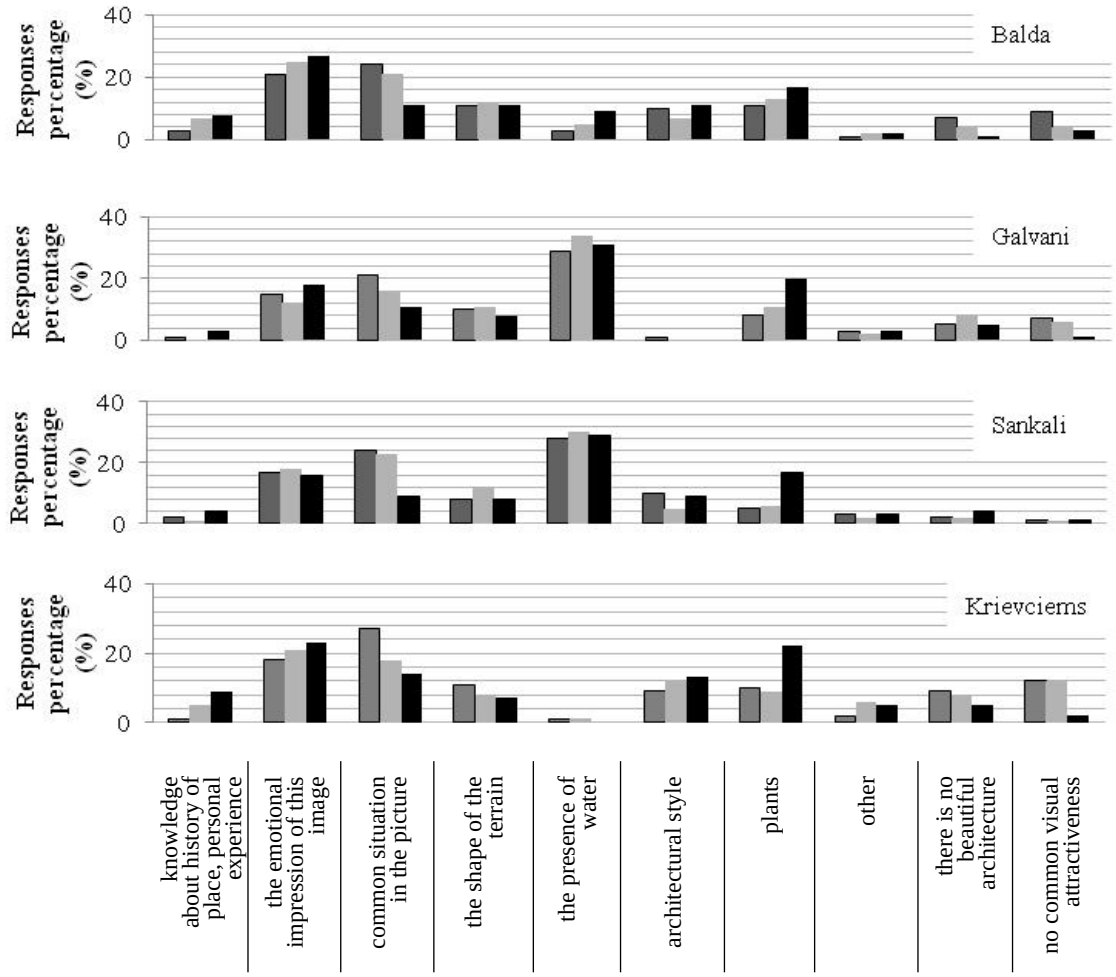

Figure 11. The most pleasant landscape parameters assessed in Balda watermill, Galvani small-scale HPP, Sankali watermill/small-scale HPP, and Krievciems watermill/small-scale HPP: ■ Latvian/general public, ■ Latvian/related to art, ■ abroad/related to art.

values between abroad-group and local groups (Figure 10). Of local inhabitants related to art, the answer '+2 beautiful enough' had the highest percent of responses; the respondents living abroad valued this territory lower - '+1 almost beautiful'. For the group by general public not related to art, the territory with ruins seemed to be beautiful, but not as often as local and foreign respondents groups related to art. The landscape parameters 'plants', 'no common visual attractiveness' and 'common situation in picture' had the highest fluctuations in percents of responses (Figure 11).

Landscape assessment data from Questionnaire No. 1, confirmed less responses (nine) for decision making. The results show only an approximate assessment of these territories.

General results show that each respondents group cultivates them own mental landscapes. The perception value is selected through one's own personal experience, in accordance with personal history, social practices and cultural background (Sautter, 1979), and information which is daily received. Authors Crang and Tavlou (2001), and Michelin (2011) speak of 'subterranean' landscape, the non-visible part of the landscape. That landscape is hidden in each mind and related to personal experience. 'The discussion in a participatory process related to landscape planning must not only focus on concrete landscape elements such as spectacular trees, hedge networks or noticeable buildings, but also has to enlarge its purpose to include the feelings, meanings and values that people attach to what they perceive' (Michelin, 2011). Specialists have to confront the fact that different people or groups may perceive the same landscape in different ways, and characteristic of perceptions may change over time (Wascher, 2005).

Conclusions

1. Public notions concerning researched landscapes reveal that the landscapes in these territories are mainly critically assessed; however, in the assessment of pictures the results are different, and the value of these territories has mainly a positive assessment. The contribution of Latvian people's knowledge regarding improvement in the landscapes situations in researched territories has to be realized.
2. Important impacts in assessment of researched territories is from notions concerning researched landscapes and have to be used to make further decisions regarding landscape politics.
3. In the assessment of landscape territories by employing different groups of people, the assessments were mostly different in the case of Krievciems. The differences in valuation should be taken into consideration when ruined territories are developed with the aim to bring them to the public use development, for example to the tourism market.

Acknowledgements

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References

1. Arthur L.M., Daniel T.C., Boster R.S. (1977) Scenic assessment: an overview. *Landscape Planning*, 4, pp. 109–129.
2. Bell S., Penēze Z., Nikodemus O., Montarzino A., Grīne I. (2007) The Value of Latvian Rural Landscape. In: Roca Z., Spek T., Terkenli T., Plieninger T., and Höchtl F. (eds) *European Landscapes and Lifestyles: The Mediterranean and Beyond*. Edições Universitárias Lusófonas, Lisbon, pp. 1–19.
3. Briggs D.J., France J. (1980) Landscape evaluation: A comparative study. *Journal of Environmental Management*, 10, pp. 263–275.
4. Carlson A. (1986) Reconstructing the aesthetics of architecture. *Journal of Aesthetic Education*, 20, pp. 21–27.
5. Cassatella C. (2011) Assessing Visual and Social Perceptions of Landscape. In: Cassatella C., Peano A. (eds), *Landscape Indicators: Assessing and Monitoring Landscape Quality*, Springer, London, pp. 105–140.
6. European Landscape Convention (2000) Council of Europe. Available at: http://conventions.coe.int/Treaty/en/ Treaties/html/176.htm, 18 March 2011.
7. Crang M., Tavlou P. (2001) The city and topologies of memory. *Environment Planning D, Society and Space*, 19, pp. 161–177.
8. Daniel T.C., Boster R.S. (1976) *Measuring landscape aesthetics: the scenic beauty estimation method*, U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station, 66 p.
9. Fairweather J.R., Swaffield S.R. (2004) *Public Perceptions of Outstanding Natural Landscapes in the Auckland Region*, Research Report No. 273, Lincoln University, New Zealand, 79 p.

10. Jones M., Stenseke M. (2011) The Issue of Public Participation in the European Landscape Convention. *The European Landscape Convention Challenges of Participation*, Springer, London, pp. 1–23.
11. Kaplan R. (1979) Visual resources and the public: An empirical approach. In: Elsner G.H., and Richard C.S. (eds) *Proceedings of our national landscape: a conference on applied techniques for analysis and management of the visual resource*, U.S. Department of Agriculture, Berkeley, pp. 514–523.
12. Michelin Y., Joliveau T., Planchat-Héry C. (2011) Landscape in Participatory Processes: Tools for Stimulating Debate on Landscape Issues? A Conceptual and Methodological Reflection from Research-Action Projects in France. In: Jones M., Stenseke M. (eds) *The European Landscape Convention. Challenges of Participation*, Springer, London, pp. 145–173.
13. Pidža M. (2011) Visual Quality Evaluation Approaches of Sacral Landscape of Latgale. In: Annual 17th International Scientific Conference Proceedings (Volume No 2). *Research for Rural Development 2011*, Latvia University of Agriculture, Jelgava, pp. 189–192.
14. Pitt D.G., Sube E.H. (1979) The Q-Sort method: Use in Landscape Assessment Research and Landscape Planning, In: Elsner G.H., Richard C.S. (eds) *Proceedings of our national landscape: a conference on applied techniques for analysis and management of the visual resource*, U.S. Department of Agriculture, Berkeley, pp. 227–234.
15. Sautter G. (1979) *Le paysage comme connivence.* (Landscape as collusion). Hérodote, Paris, pp. 40–67. (in French).
16. Siļķe K. (2008) Ūdens enerģijas izmantošanas vēsture Latvijā (The History of Water Energy's use in Latvia). In: *Mazā hidroenerģētika Latvijā*, Latvijas mazās hidroenerģētikas asociācija, Riga, 6–11. lpp. (in Latvian).
17. Stephenson W. (1953) *The study of behavior: Q-Technique and Its methodology*, University of Chicago Press, Chicago, 376 p.
18. Teivens A. (1985) *Latvijas dzirnavas* (Latvian Mills). Daugava, Stockholm, 298. lpp. (in Latvian).
19. Wascher M.D. (2005) *European Landscape Caracter Areas – Typologies, Cartography and Indicators for the Assessment of Sustainable Landscapes. Cartography and Indicators for the Assessment of Sustainable Landscapes*. Alterra Report, Wageningen, 148 p.
20. Zemdega A. (2004) *Toreiz Lubes dzirnavās* (In That Time in Watermill of Lube). Third edition, Rīga, 200. lpp. (in Latvian).

MIKLOUHO-MACLAY PARK - THE OBJECT OF HISTORICAL, CULTURAL AND ARCHITECTURAL HERITAGE

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Abstract
The article is devoted to the analysis of historical, cultural, and architectural importance of Miklouho-Maclay park, a monument of landscape art. It examines the archive data about the family of the famous traveler, ethnographer, anthropologist Mykola Mykolayovych Miklouho-Maclay who lived in Malyn (Zhitomir district Ukraine) at the end of XIX and the beginning of XX century, his contribution to the development of landscape art. It is shown that the park contains 57 species of arboreal-shrub plants including 34 species of trees, 22 shrubs, and one shrubby liana. 23 of them (40%) are introduced species. The author offers the direction of parkland reconstruction and points out recommendations on territory zoning.
Key words: park, the monument of landscape art, introduced decorative species.

Introduction

As a rule, ancient parks convey the historical and cultural information. The City Park of Culture and Recreation in Malyn, Zhytomyr Region, is named after the famous Ukrainian traveler, ethnographer, ethnologist, anthropologist, biologist, and humanist of the past century M.M. Miklouho-Maclay. The first information about the purchase of the estate appeared in his letter to his friend A. Meshcherskiy dated 1873, December 11, where he wrote: "I am not happy with the things you told me about my mother, but I know the estate was her (mother's) desire."

Maclay's mother, Kateryna Semenivna, moved to Malyn with her older son Sergiy and her daughter Olga. Soon, a new two-story brick house along with some other buildings including a stable, shed for cattle, and hen house were built. The bakery and a deep well were already there. The orchard was planted; flowerbeds and a small fish pond were constructed. The main building was located in the big ancient park where later a riding hall, an area for croquet, and two arbours were made.

In 1886 Myklouho-Maclay visited his mother, in Malyn. He admired the way of life, customs, and traditions of the local people. He was fond of folk dances, songs, and games of local young people on the Irsha river. The scientist was interested in Drevlyan's origin and their history. He visited nearby villages and studied anthropological constitution of Polishchuks. Following August, Mykola Mykolayovysh visited Malyn again. Unfortunately, his visit was shorted by illness. He died shortly thereafter.

After the death of his mother Kateryna Semenivna, the estate was estimated at 200,000 roubles in 1905. The park with a lot of rare 500-600-year-old trees was the most valuable. It was planned in a landscape style. Unfortunately, most of the plants including those brought by Myklouho-Maclay from New Guinea, have not survived to our days.

During 1917-1941 the park fell into decay. Nobody took care of it, most of the introduced species perished on its territory. As a result, most of its dendroflora now are represented by aboriginal arboreal and shrubby species. During the Second World War, some trees were cut by Germans; the park became the execution ground for captured Resistance fighters.

Revival of the city park began in the 1960's through the 1970's: avenues were cleaned and asphalted, ponds were cleared and the boating station was built. The summer theatre and children's playground with carousels and attractions were also constructed there; though, with time, they became obsolete and consequently were dismantled.

The landscaped park obtained its status on December 22, 1973 by the order of the Zhytomyr Regional Executive Committee. According to the decision, the area was 43 hectares large. Later, in 1973-1992, it was diminished to 29.6348 hectares due to the construction of a nearby school, kindergarten, and private houses (Figure).

While there is enough information about the Miklouho-Maclay, the information about arboreal-shrub composition of those days and of today's park is practically missing. It is known only that the park was created on the base of oak and pine plantings in a landscape style with the introduction of new species. Unfortunately, we have no information about the species brought from different countries including New Guinea.

The aim of our investigation was to determine the species composition of the current park's dendroflora.

Materials and Methods

In our investigation, archived materials of State archive of Zhytomyr region, Central State Historical Archive of Ukraine in Kyiv, commercial and industrial statistics' materials of XIX century and M.M. Myklouho-Maclay's work collections were

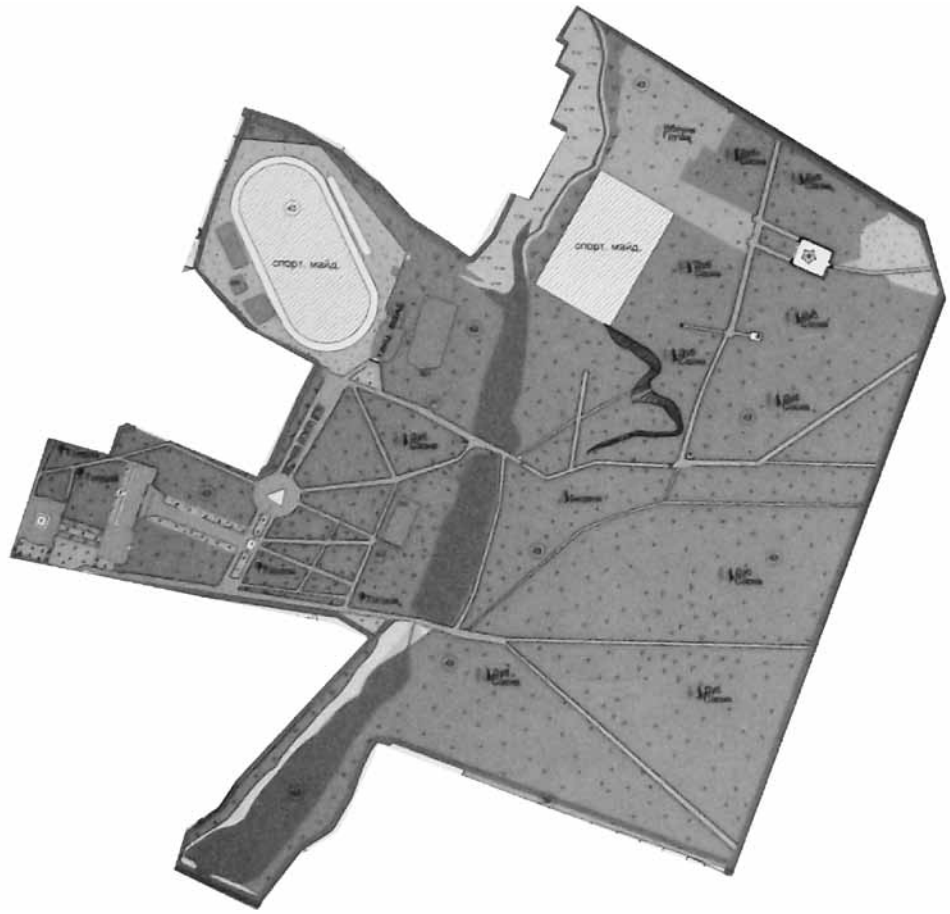

Figure. The scheme of Miklouho-Maclay's park.

used. Research was done in Malyn Zhitomir district Ukraine.

The qualitative structure of park's dendroflora was identified with the help of Atlas 'Trees and Bushes of Western Ukraine' (Бродович, 1979).

Results and Discussions

Besides the historical and memorial value, the research of the park has also scientific significance. In particular, its territory preserved the landscape planning, which creates picturesque views. The age of many trees, especially *Quercus* and *Pinus*, is more than 150 years. Our preliminary counts show that 57 species of arboreal-shrubby plants, including 34 species of trees, 22 shrubs, and one shrubby liana, grow in the park. Most of them are local aboriginal species (Table).

The quantitative analysis of plant species composition showed that the group of decorative and fruit species comparatively recently introduced into the park's dendroflora was represented by 23 species and accounted for 40% of all species. Thus, the base of the park is formed by aboriginal plants, which are more typical for a forest landscape, than for a park one. Therefore, while working out the reconstruction project, it is recommended to introduce a greater percentage of decoratively valuable arboreal-shrub species.

On the most park's territory, trees are in good sanitary condition. However, some plants, especially *Populus nigra* and *Salix babylonica* growing on the pond banks are nearing their age limit and losing their biological hardiness. Such trees should be closely monitored, timely eliminated, and replaced. More thorough examination of vegetation will be conducted during the functional zoning of park's territory.

The territory of investigated park comprises a complicated set of areas with arboreal-shrub planting in different degrees of preservation and complex of grounds of sporting, recreational, and cultural value as well as an unfinished building of sporting complex. In current condition, without functional zoning of park's territory its re-planning, finishing the sporting complex construction, and equipping children's playgrounds are forbidden by the Law as the park's territory is protected.

To optimize the usage of the territory of park-monument of landscape gardening art, the activity on its territory should comply with the Law. After the approval of new borders, the functional zoning should

Table 1

Dendroflora Composition of Miklouho-Maclay Park

No	Species	Introduced species	No	Species	Introduced species
Family Aceraceae			26	*Pinus silvestris L.*	-
1	*Acer platanoides L.*	-	27	*Pinus nigra Arn.*	+
2	*Acer sacharinum L.*	+	28	*Thuja accidentalis L.*	+
3	*Acer negundo L.*	+	**Family Rosaceae**		
4	*Acer tataricum L.*	-	29	*Armeniaca vulgaris L.*	-
5	*Acer tataricum f. minor*	-	30	*Sorbus aucuparia L.*	-
Family Berberidaceae			31	*Pyrus communis L.*	-
6	*Berberis orientalis L.*	+	32	*Malus domestica Borkh.*	-
Family Betulaceae			33	*Malus prunifolia (Willd.) Borkh.*	+
7	*Betula pendula L.*	-	34	*Prunus divaricata Ledeb.*	+
8	*Carpinus betulus L.*	-	35	*Cerasus domestica L.*	-
9	*Corylus avellana L.*	-	36	*Rubus caesius L.*	-
Family Carpifoliaceae			37	*Rubus idaeus L.*	-
10	*Sumbucus nigra L.*	-	38	*Spiraea japonica L.*	+
11	*Viburnum opulus L.*	-	39	*Spiraea x vanhouttii Zabel*	+
Family Celestraceae			40	*Rosa canina L.*	-
12	*Evonymys verrucosa L.*	-	41	*Rosa caesia L.*	-
13	*Evonymys europea L.*	-	42	*Physocarpus opulifolia Maxim*	+
Family Cupressaceae			43	*Chaenomeles japonica (Thunb.) Lindi*	+
14	*Juniperus sabina L.*	+	44	*Crataegus curvesipala L.*	-
Family Fabaceae			45	*Crataegus ucrainica Pojark.*	-
15	*Robinia psevdoacacia L.*	+	**Family Saliaceae**		
16	*Genista tinctiria L.*	-	46	*Salix babylonica L.*	+
17	*Chamaecytisus ruthenicus (Fisch. ex Wołłosz.) Klásk.*	-	47	*Salix pentandra L.*	-
18	*Laburnum anagyroides Med.*	+	48	*Salix fragilis L.*	+
19	*Caragana arborescens Lam.*	+	49	*Salix caprea L.*	-
Family Fagaceae			50	*Salix alba L.*	-
20	*Quercus robur L.*	-	51	*Populus nigra L.*	-
21	*Quercus rubra L.*	+	52	*Populus tremula L.*	-
Family Hippocastanaceae			**Family Tiliaceae**		
22	*Aesculus hyppocastanum L.*	+	53	*Tilia cordata Mill.*	-
Family Oleacea			**Family Ulmaceae**		
23	*Syringa vulgaris L.*	+	54	*Fraxinus excelsior L.*	-
Family Pinaceae			55	*Ulmus laevis Pall.*	-
24	*Picea pungens Engelm.*	+	56	*Fraxinus viridis Michx.*	+
25	*Picea abies (L.) Karsten*	-	**Family Vitaceae**		
			57	*Partenocyssus qiunquefolia(L.) Planch.*	+
Introduced species (total)		**23**			

Comment: «+» - introduced species, «-» - indigenous species.

be implemented according to the Law of Ukraine 'About the Naturally-Protected Fund' from 1992, June 6 # 2456 – XII.

According to the functional setting, the following zones should be distinguished: I. Display zone (zone of excursions): 1a – display parkland (zone of excursions), 1b – a zone of the limited recreation on the pond shore protective belt. II. Administrative zone: 2a – zone of administrative and auxiliary buildings, 2b – zone of sanitary recreation (existent children's playgrounds, attractions, sporting grounds, etc.), 2c – reserve economic zone for the construction of

administrative and auxiliary buildings and buildings for stationary and organized recreation and sport activities.

Conclusions

After the investigation of the park-monument of a landscape gardening art, we came to the conclusion that it possesses historical, cultural, and architectural values. Due to intensive construction, the area of the park diminished from 43.0 to 29,6348 hectares. Its dendroflora composition is represented by 57 species of arboreal and shrubby plants including 34 trees, 22 shrubs, and one shrubby liana.

The basis of the park consists of the aboriginal species which are typical of the forest type of landscape. Therefore, during the reconstruction more introduced species should be planted.

To optimize the park's area, its zoning with the allocation of two distinctive zones: display and administrative should be implemented.

References

1. Tumarkin D.D. (1985) Gladstone on Miklouho-Maclay. *Newsletter of the Miklouho-Maclay Society of Australia*, Vol. 6, No 4, Sydney, pp. 3–4.
2. Tumarkin D.D. (1986) Letter to the Editor. *Newsletter of the Miklouho-Maclay. Society of Australia*, Vol. 7, No 2, Sydney, p. 13.
3. Миклухо-Маклай Н.Н. (1953) Собрание сочинений (Collected works). Т. 4, Наука, Москва, 416 с. (in Russian).
4. Похилевич Л. (1882) Роспись землевладельцев в Радомышльском уезде Киевской губернии. (Painting of the Landowners in Radomyshl district in Kyiv province). Топография Киевопечерской лавры, Киев, сс. 144–157. (in Russian).
5. Центральний державний історичний архів України у Києві (1905) (Central State Historical Archive of Ukraine in Kyiv). Ф.276, Оп.1., спр. 453. (in Ukrainian).
6. Лазанська Т.І. (1999) Історія підприємництва в Україні (на матеріалах торгово-промислової статистики XIX ст.) (The History of Enterprise in Ukraine (on the information of commercial and industrial statistics of XIX century)). Інститут історії України Киев, 282 с. (in Ukrainian).
7. Державний архів Житомирської області (1897) (State Archiveof Zhytomyr Region). Ф.568., оп.1., спр. 3. (in Ukrainian).
8. Бродович Т.М. (1979) Деревья и кустарники запада УССР. Атлас. (Trees and Bushes of Western Ukraine, USSR, Atlas). Вища школа, Львов, Редакция: Бродович Т.М., Бродович М.М., 250 с. (in Russian).

PROBABILITY DISTRIBUTIONS OF WAVE HEIGHTS IN THE LITHUANIAN COAST

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Abstract
Since discovering that signals of random waves submit to the known laws of probability, this became widely used in engineering and energetics for probability distributions analysis of wave height. From an energetic point of view, it is necessary to know the average wave height in, for example, highly wavy (1% probability), medium wavy (25% probability) or non-wavy (95% probability) years. Whereas, maximum multi-year value of wave height characteristics is essential for engineering resistant wave energy converters that could withstand severe marine conditions. Average and maximum annual values of wave height data collected from Klaipėda coastal hydrometeorological station are used for this study. Probability distributions of average and maximum wave heights in the Lithuanian coast are analysed in this paper. The best fitting is obtained using HYFRAN and EASY FIT software. Both, a test for independence (Wald-Wolfowitz) and stationarity test (Kendall) are carried out for every time series using HYFRAN software. Maximum likehood method is selected for distribution estimation. Fitting is determined using chi-square test and the best fitting is verified with comparison (BIC and AIC) criterion. Fitting for one of the most commonly used distributions in the analysis of wave climate – Rayleigh distribution – cannot be determined with HYFRAN software. For this purpose, EASY FIT software is used additionally. The fit of the distribution is evaluated via the chi-square test similarly. Calculated wave heights based on lognormal probability distribution that fits best according to HYFRAN software are similar to those calculated using Rayleigh probability distribution.
Key words: probability distributions, Baltic Sea, wave height.

Introduction

The statistical theory of random signals for electrical noise analysis was developed in 1944 by S. O. Rice (Rice, 1944), M. S. Longuet-Higgins applied this theory to the random water surface elevation of water waves. It emerged that the parameters of a random wave signal follow known probability laws (Longuet-Higgins, 1952). As a result, the analysis of probability distributions of wave heights in engineering and energetics is used to the present day.

Gumbel distribution was used to determine wave climate and wind speed parameters during the period of tropical hurricanes in the Caribbean Sea in 2002 (Calverley et al., 2002). Generalized extreme value (GEV) distribution was used for the coastal region of East Anglia (UK) in 2010 to analyze extreme events and estimate climate change implication on inshore waves and the occurrence of extreme events (Chini et al., 2010).

An attempt to fit normal distribution for the Black Sea waves in Filyos region (Turkey), where a new sea port is planned, failed. It was estimated that statistical distribution of surface profile of the records containing extreme waves deviates from normal distribution (Bilyay et al., 2011).

It is common that in various marine areas a number of distributions is used for different studies. For example, at the end of last century increased marine activities like offshore mineral and oil exploration, utilization of wave energy, construction of marine structures and harbors caused a demand for accurate information about wave climate in the Arabian Sea. The available atlases of averaged visual wave statistics at that time provided information that differed from one another (Muraleedharan et al., 1990).

In 1990 the comparative study of distributions of wave heights from these atlases was made for an area off Trivandrum. The long-term distributions of significant wave heights were tested with Weibull, Gumbel, Rayleigh, exponential and lognormal models. The best fit was obtained for Weibull probability density function (Muraleedharan et al., 1990).

Weibull and Rayleigh probability distributions are most commonly used for analysis of wave heights. This is not accidental as Rayleigh probability distribution is often characterized as the special case of Weibull distribution.

The demerits of Rayleigh distribution are that it does not always fit for the nearshore conditions and in some cases the enlarged values of maximum wave heights can be obtained. Therefore, Rayleigh distribution is often modified for the nearshore conditions (Thornton et al., 1983). There are even attempts to incorporate both distributions and to adapt complex Rayleigh-Weibull distribution (Mai et al., 2010).

Forecasting of the wave heights while considering waves from energetic point of view is important. This is essential both for evaluating energetic potential and for designing and maintenance of wave energy converters.

The objective of this article is to test probability distributions for wave heights and to obtain best fitting in the Lithuanian nearshore conditions. In particular

because the published probability fitting studies for the Baltic Sea of 40 or more years visual observation data are scarce or even absent.

Materials and Methods

Visual observations data from Klaipėda coastal hydrometeorological station was used for this study. Maximum wave height from 1961-2010 and annual average wave height from 1970-2010 were used. The intent to use same periods for both time series failed because since 1969 in coastal observations register for lower than ~ 0.5 m waves no average wave heights are noted. Therefore, it is difficult to calculate average annual wave heights.

World Meteorological Organization (WMO) indicates the following mostly used for wave height analysis probability distributions: normal, lognormal, gamma, Weibull, exponential, Rayleigh, generalized extreme value, Gumbel, Fisher-Tippet and generalized Pareto (World..., 1998).

Software that is used for this study is HYFRAN and EASY FIT. Both are selected because they allow performing best fitting analysis for most of WMO mentioned probability distributions.

HYFRAN software enables choosing empirical probability formula. For this study formula of Chegodayev is used:

$$P = \frac{m - 0.3}{n + 0.4}; \quad (1)$$

where n – number of observation years, m – number of years in a row.

Any distribution is reliable only for homogenous and independent data sets. Therefore, for both time series used in this study test for independence (Wald-Wolfowitz) and additionally stationarity test (Kendall) are performed with HYFRAN software. Results of these tests indicate absence of autocorrelation and trend in time series.

All probability distributions used in this study are presented in Table 1.

For distribution estimation maximum likehood method is used. Fitting is obtained applying chi-square

Table 1

Probability distributions used in this study

No.	Distribution	Probability density function	Cumulative density function
1	Normal	$f(x)=\frac{1}{\alpha\sqrt{2\pi}}\exp\left\{-\frac{(x-u)^2}{2\alpha^2}\right\}$	$F(x)=\frac{1}{\sqrt{2\pi}}\int_{-\infty}^{x}\exp^{-t/2}dt$
2	Lognormal	$f(x)=\frac{1}{x\alpha\sqrt{2\pi}}\exp\left\{-\frac{(\ln x-u)^2}{2\alpha^2}\right\}$	$F(x)=\Phi\left(\frac{\ln(x)}{\alpha}\right)$
3	Gamma	$f(x)=\frac{\left(\frac{x-\mu}{\beta}\right)^{c-1}\exp\left(-\frac{x-\mu}{\beta}\right)}{\beta\cdot\Gamma(c)}$	$F(x)=\frac{\Gamma_x(c)}{\Gamma(c)}$
4	Exponential	$f(x)=\frac{1}{\alpha}\exp\left\{-\frac{x-m}{\alpha}\right\}$	$F(x)=1-\exp(-x/\alpha)$
5	Gumbel	$f(x)=\frac{1}{\alpha}\exp\left[-\frac{x-u}{\alpha}-\exp\left(\frac{x-u}{\alpha}\right)\right]$	$F(x)=1-\exp\left[-\exp\left(\frac{x-u}{\alpha}\right)\right]$
6	GEV	$f(x)=\frac{1}{\beta}\left[1+c\left(\frac{x-\mu}{\beta}\right)\right]^{-1/c-1}$	$F(x)=\exp\left(-\left(1-c\cdot\left(\frac{x-\mu}{\beta}\right)\right)^{1/c}\right)$
7	Weibull	$f(x)=\frac{c}{\alpha}\left(\frac{x}{\alpha}\right)^{c-1}\exp\left[-\left(\frac{x}{\alpha}\right)^{c}\right]$	$F(x)=1-\exp\left[-\left(\frac{x}{\alpha}\right)^{c}\right]$
8	Rayleigh	$f(x)=\frac{1}{\alpha\sqrt{2\pi}}\exp\left\{-\frac{(x-u)^2}{2\alpha^2}\right\}$	$F(x)=\frac{1}{\sqrt{2\pi}}\int_{-\infty}^{x}\exp^{-t/2}dt$

x - random variable; u - mean; α - standard deviation; Φ - cumulative distribution function of the normal distribution; μ - location parameter; β - scale parameter; Γ - gamma function; Γ_x - incomplete gamma function; m - random variable mean; c – shape parameter

test. HYFRAN software verifies the adequacy of fit by accepting or rejecting the null hypothesis: the underlying distribution of the sample according to chi-square test result fits the theoretical distribution.

The best fit is gained with BIC and AIC criterions. The assessment of the quality of a fitted model, Akaike information criterion (AIC) was introduced in 1974. It can be adapted in many various occasions and consists in minimizing an information measure. The information criterion definition is:

$$AIC(f) = -2\log L(\theta, x) + 2k; \quad (2)$$

where $L(\theta, x)$ is the likehood function and *k* is the number of parameters. According to Akaike (1974), the model that better explains the data is the one with the lowest Akaike information criterion.

A Bayesian extension of the of the minimum Akaike information criterion concept is Bayesian information criterion (BIC). It is defined:

$$BIC(f) = -2\log L(\theta, x) + k\log(n); \quad (3)$$

where *n* is the sample size. Of all the models the one with the lowest Bayesian information criterion is considered to be the best (World…, 2009).

With HYFRAN software it is not possible to evaluate fitting of Rayleigh distribution. Due to this, EASY FIT software is additionally used in this study. The fitting is obtained similarly – applying the chi-square test.

Results and Discussion

Basic statistics of wave heights used in this study are presented in Table 2.

Table 2

Basic statistics of wave heights

Basic statistics	Annual average wave height	Annual maximum wave height
Number of years data	41	50
Minimum	0.50 m	2.5 m
Maximum	0.93 m	6.0 m
Average	0.68 m	4.0 m
Standard deviation	0.09	0.82
Median	0.67 m	4.0 m
Coefficient of variation C_v	0.15	0.21
Skewness coefficient C_s	0.58	0.72

Wald-Wolfowitz test for average annual wave heights (Fig. 1) shows that observations are independent (there is no autocorrelation). Kendall test shows existence of a trend. A gradually decreasing curve of annual average wave heights is apparent in Fig. 1.

All probability distributions that fit average annual wave heights according to HYFRAN software chi-square test results are listed in Table 3. To determine

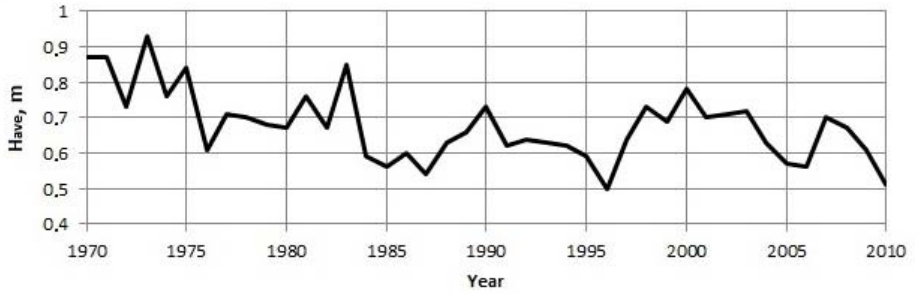

Figure 1. Average annual wave heights in Klaipėda coast.

Table 3

Applicable probability distributions for average wave heights for the coast of Klaipėda

Probability distributions	Chi-square statistic	p-value	BIC criterion	AIC criterion
GEV	6.41	0.17	-65.43	-70.07
Gumbel	5.63	0.34	-68.23	-71.66
Normal	2.12	0.83	-66.34	-69.79
Lognormal	4.46	0.48	-68.65	-72.07
Gamma	4.46	0.48	-68.15	-71.58

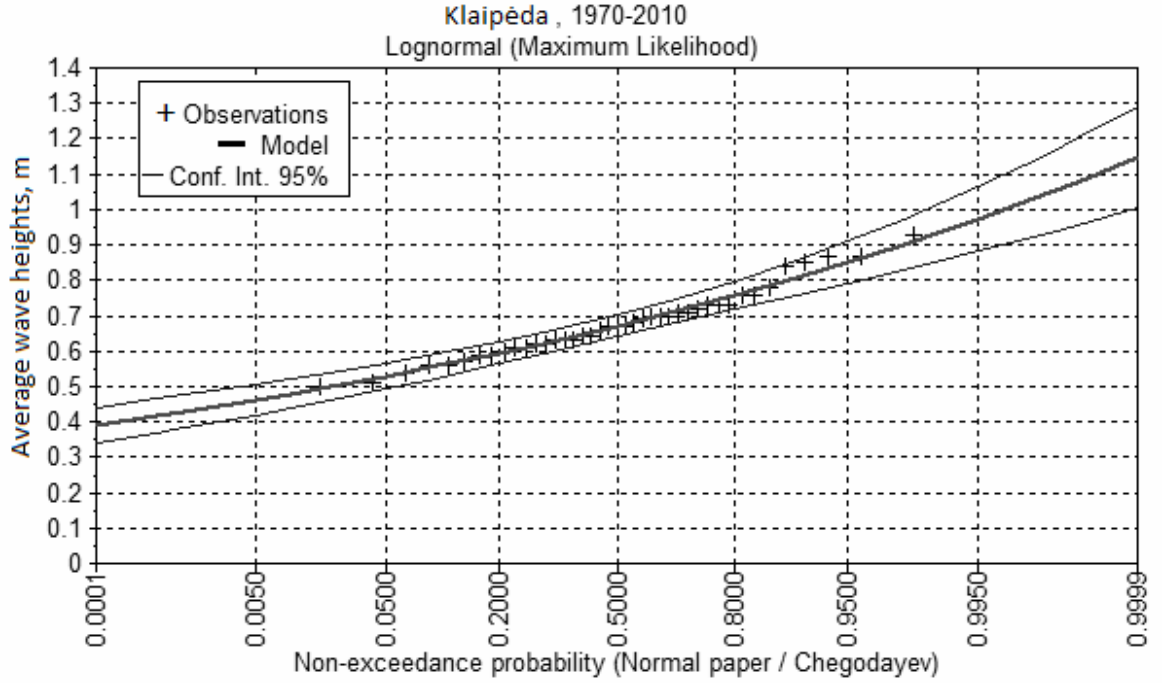

Figure 2. Lognormal distribution of average annual wave heights in Klaipėda coast.

Figure 3. Maximum annual wave heights in Klaipėda coast.

which of these distributions provide best fitting, the BIC and AIC criterion values are calculated and listed in the same table.

The best fit is obtained for lognormal probability distribution (Fig. 2). This is indicated by both – BIC and AIC criteria (-68.65 and -72.07 correspondently). For calculation of average annual wave heights in Klaipėda coast depending on probability and return period, it is preferable to use this distribution (Table 4).

Wald-Wolfowitz test for maximum annual wave heights (Fig. 3) shows that observations are independent (there is no autocorrelation). Similarly as for average annual wave heights Kendall test shows existence of a trend. A gradually decreasing curve of maximum annual wave heights (Fig. 3) follows the accordingly decreasing curve of average annual wave heights.

HYFRAN software chi-square test results indicate that there is no applicable probability distribution for maximum annual wave heights in Klaipėda coast; null hypothesis (distribution of the sample fits the theoretical distribution) is rejected in all cases. Empirical moments test is applied in order to confirm these results. This test marks only one fitting probability distribution for maximum wave heights – lognormal (Fig. 4). In such case there is no need to use BIC and AIC criteria test additionally. For calculating maximum annual wave heights in Klaipėda coast depending on probability and return period lognormal probability distribution is used (Table 4).

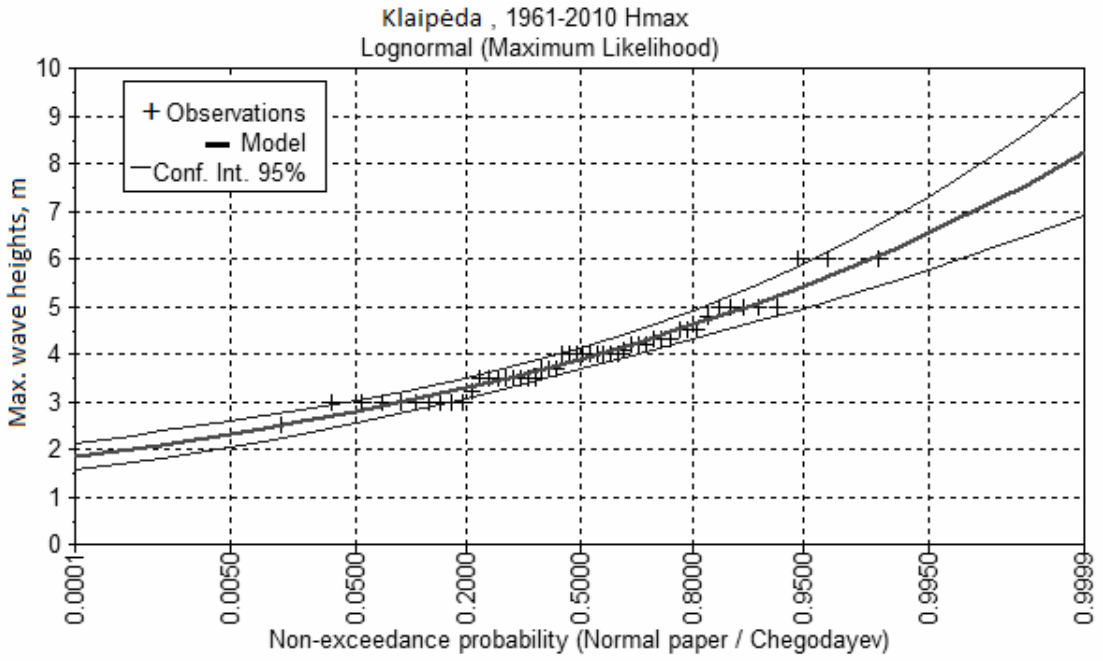

Figure 4. Lognormal distribution of maximum annual wave heights in Klaipėda coast.

Table 4

Average and maximum wave heights in Klaipėda coast based on lognormal distribution

Characteristic of the year	Probability P %	Return period T years	Average wave height m	Maximum wave height m
Highly wavy	1	100	0.94	6.2
Wavy	5	20	0.85	5.4
Medium wavy	25	4	0.74	4.5
Median	50	2	0.67	3.9
Medium non-wavy	75	4	0.61	3.4
Non-wavy	95	20	0.53	2.8
Highly non-wavy	99	100	0.48	2.4

To evaluate the suitability of fit for the Rayleigh distribution commonly used for wave height analysis, in this study EASY FIT software is used. EASY FIT software works differently from HYFRAN. It does not indicate immediately if the probability fits or not, there is no BIC and AIC criteria tests. This software, especially designed to simplify distribution fitting procedures, ranks 61 different distributions for every given observation data. Ranking is provided using three different goodness of fit tests, including chi-square. The fitting of the ranked probability distributions can be estimated by using calculated p-value, degrees of freedom and chi-square statistics values (Table 5).

Table 5

Results of Rayleigh distribution chi-square test for wave heights in Klaipėda coast

	p-value	Deg. of freedom	Chi-square statistic
Average annual wave heights	0.97	5	0.96
Maximum annual wave heights	0.91	4	1.01

Referring to associated probability table (Appendix 1) and results of goodness of fit test for Rayleigh distribution, the conclusion can be made

Table 6

Average and maximum wave heights in Klaipėda coast based on Rayleigh distribution

Characteristics of the year	Probability P %	Return period T years	Average wave height m	Maximum wave height m
Highly wavy	1	100	0.95	6.2
Wavy	5	20	0.86	5.5
Medium wavy	25	4	0.74	4.5
Median	50	2	0.66	3.9
Medium non-wavy	75	4	0.60	3.4
Non-wavy	95	20	0.53	2.8
Highly non-wavy	99	100	0.50	2.6

that this distribution provides a high fit for both average and maximum wave heights in Klaipėda coast. Average and maximum annual wave heights in Klaipėda coast depending on probability and return period using Rayleigh distribution are presented in Table 6.

Conclusions

Results of average and maximum wave heights obtained by using different software and applying two different probability distributions are similar. It is difficult to assess the accuracy for the obtained results due to the scarce number of similar studies. To some extent the accuracy can be indicated by comparing the median average and maximum wave heights gained from calculating basic statistics and median year average and maximum wave heights calculated depending on probability and return period. An average wave height is 0.67 m from basic statistics, 0.67 m from lognormal distribution and 0.66 m from Rayleigh distribution. Maximum wave height is 4.0 m; 3.9 m and 3.9 m respectively. The calculation error resulted from inaccuracy of visual observation is compensated by using long-term observation data. Marine engineers for calculating multi-year maximum and average wave height value in Klaipėda coast can use both, lognormal and Rayleigh probability distributions.

Acknowledgements

The author would like to acknowledge EPA Department of Marine Research in Lithuania for providing Klaipėda coastal hydrometeorological station data.

Appendix 1

Chi-square values for up to 10 degrees of freedom that are associated with various probabilities

Degrees of freedom	Probabilities									
	0.95	0.90	0.70	0.50	0.30	0.20	0.10	0.05	0.01	0.001
1	0.004	0.016	0.15	0.46	1.07	1.64	2.71	3.84	6.64	10.83
2	0.10	0.21	0.71	1.39	2.41	3.22	4.61	5.99	9.21	13.82
3	0.35	0.58	1.42	2.37	3.67	4.64	6.25	7.82	11.35	16.27
4	0.71	1.06	2.20	3.36	4.88	5.99	7.78	9.49	13.28	18.47
5	1.15	1.61	3.00	4.35	6.06	7.29	9.24	11.07	15.09	20.52
6	1.64	2.20	3.83	5.35	7.23	8.56	10.65	12.59	16.81	22.46
7	2.17	2.83	4.67	6.35	8.38	9.80	12.02	14.07	18.48	24.32
8	2.73	3.49	5.53	7.34	9.52	11.03	13.36	15.51	20.09	26.13
9	3.33	4.17	6.39	8.34	10.66	12.24	14.68	16.92	21.67	27.88
10	3.94	4.87	7.27	9.34	11.78	13.44	15.99	18.31	23.21	29.59

References

1. Akaike H. (1974) A new look at the statistical model identification. *IEEE transactions on automatic control*, AC-19(6), pp. 716–723.
2. Bilyay E., Ozbahceci B.O., Yalciner A.C. (2011) Extreme waves at Filyos, Southern Black Sea. *Natural Hazards and Earth System Sciences*, 3, pp. 659–666.
3. Calverley M.J., Szabo V.J., Cardone E.A., Orelup E.A., Parsons M. (2002) Wave climate study on the Caribbean Sea. *Preprints of the 7th International workshop on wave hindcasting and forecasting*. Alberta, Canada. Proceedings available from Environment Canada, Downsview, Ontario, pp. 1–12.
4. Chini N., Stansby P., Leake J., Wolf J., Robert-Jones J., Lowe J. (2010) The impact of sea level rise and climate change on inshore wave climate: a case study for East Anglia. *Coastal Engineering*, 57, pp. 973–984.
5. Longuet-Higgins M.S. (1952) On the statistical distribution of the heights of sea waves. *Journal of Marine Research*, 11(3), pp. 245–266.
6. Mai S., Wilhelmi J., Barjenbruch U. (2010) Wave height distributions in shallow waters. In: Smith J.Mc., Lynett P. (eds) Coastal Engineering 2010. *Proceedings of the 32nd International conference*, Shanghai, China, pp. 1–6.
7. Muraleedharan G., Unnikrishnan Nair N., Kurup P.G. (1990) Long-term wave characteristics off Trivandrum. *Mahasagar*, 23, pp. 1–12.
8. Rice S.O. (1944) Mathematical analysis of random noise. *Bell System Technical Journal*, 23, pp. 282–332.
9. Thornton E.B., Guza R.T. (1983) Transformation of wave height distribution. *Journal of geophysical research*, 88, pp. 5925–5938.
10. World Meteorological Organization (1998) *Guide to wave analysis and forecasting*. Secretariat of World Meteorological Organization, Geneva, Switzerland, 159 p.
11. World Meteorological Organization (2009) *Guide to hydrological practices. Vol. II. Management of water resources and application of hydrological practices*. Secretariat of World Meteorological Organization, Geneva, Switzerland, 302 p.

THE INFLUENCE OF CROPPING SYSTEMS DIFFERING IN INTENSITY ON MINERAL NITROGEN MIGRATION

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Abstract
The research was carried out on ASU WRI grounds in Juodkiškes village in Endocalcari Endohypogleyic Cambisol (CMg-n-w-can). Research basis is 3 different field studies. In Variant I an organic cropping system was used with manure and without mineral fertilizers and pesticides, in II - organic-mineral cropping system with manure and mineral fertilizers, using pesticides, in Variant III - mineral cropping system with mineral fertilizers and pesticides. Minimum mineral nitrogen content in soil was in the organic cropping system, and the total minimal field crop capacity - in the mineral cropping system. However, it has the highest energy efficiency of this system (ETK - 13). Minimal $N\text{-}NO_3^-$ concentration in drainage water was in the mineral cropping system. In the organic-mineral and organic cropping systems concentration of this compound increases by 11 percent (to 21.8 mg l^{-1}). The minimal concentration of ammonia nitrogen was under organic cropping conditions. The organic cropping system showed the highest runoff and maximum leaching of nitrogen compounds by drainage.
Key words: cropping systems, nitrogen, yield, concentration, leaching.

Introduction

The historical experience of anthropogenic impact on environment shows that negative economic activity characteristics, associated with inadequate assessment of the integrity of nature, are unforeseen. Soil, vegetation, atmosphere and water form a unified system, and alterations of one component inevitably change other too (Фортескью, 1985). In the second half of the twentieth century agriculture was developed in the direction of intensification. In 1930 in Lithuania NPK of active substances were 0.4 kg ha^{-1}, of manure - 2.5 tons ha^{-1}. In 1986-1990 these amounts increased to 209.5 kg ha^{-1} and 5.5 tons ha^{-1}. Similar trends were also observed around the world (Švedas, 1997). In 1970-1985 in U.S. and Western Europe the costs of 1 ha of material-energy resources rose 1.9 times, and the rates of agricultural production growth were not adequate and increased by only 1.4 times (Таран и Папцов, 1992). Economic management analysis of developed countries in recent decades has showed that agricultural intensification leads to 2 problems:

ecological one (agrolandscape pollution);

and economic (a sharp turnabout in prices is possible because of the use of basic material and energy resources, since most of them are obtained using non-renewable resources) (Таран и Папцов, 1992).

According to UNESCO data, between the main polluters on a global scale mineral fertilizers are in the 4th place (between such polluters as oil industry and vehicles). Although fertilizers aren't contaminants, but damage from them can occur during the process of diffuse pollution through various cycles of transmission, leaching, accumulation, etc. (Кант, 1988).

Recently in affluent countries, in economy-ecology relationship the so-called change of leaders can be seen, when ecological factors receive more attention and become rational scientific basis for the use of nature. These two factors have induced advancement of idea of so-called alternative agriculture. The most widespread system in the U.S. and Europe, the description of which specialists from U.S. Ministry of Agriculture formulated as early as in 1970. It is a production system, which operates entirely or almost entirely without the use of mineral fertilizers, pesticides, growth regulators and artificial feed additives (Таран и Папцов, 1992). However, there are very few data confirmed by research, which in an unbiased manner estimate organic-biological farming. Fertilizers are one of the strongest metabolic agents in agriculture. Without the use of fertilizers we cannot regulate the process of plants nutrition, to change the harvest quality. Fertilizers have a comprehensive effect on soil; they replenish soil with plant nutrients, change chemical, agrochemical and physical properties of soil and facilitate mobilization of food compounds in soil itself (Минеев, 1988). Now it is unanimously acknowledged that any reduction in anthropogenic environmental load is associated with the changes in plant productivity, usually occurring in the descending order. It is considered that mineral fertilizers in Lithuania help to get 25-35 per cent of harvest. Such evaluation of these fertilizers is very restrained, as it does not show the effect of soil on productivity growth, which is more important than additional one-time yield (Švedas et al., 2001). Most research show that average yield from organic-biological farming is very low - less than 60 per cent of crop from intensive agriculture farms (Bučienė et al., 1999; Olesen et al., 2002). However, there are also statements that efficiency of organic-biological farming is little inferior to that of traditional farming (Таран и Папцов, 1992; Edmeades, 2003; De Jager et

al., 2001). According to the data of English researchers, in 7 of 9 investigated organic agriculture farms nitrogen balance was excessive (Berry et al., 2003). Most extensive research of plants productivity under these cropping systems have been conducted in the United States. It is emphasized that in the first years, during transition to biological farming, productivity of most plants decreases (Таран и Папцов, 1992). When crop rotations are properly applied, after 5 years of stabilization of this agroecosystem productivity increases (Bate et al., 1993). In literature the impact of agriculture of various intensity on water quality is estimated as very multiple-valued. Soil water is one of the key elements reflecting pollution status of the whole geosystem (Jankauskaitė, 1993). Its quality and that of chemical elements, as well as migration of compounds define variety of natural and anthropogenic factors. Impact of these factors in space and time is quite differentiated. Some of them have a greater impact on superficial water, other - on a deeper water (Klimas et al., 1993). Many researches unanimously claim that leaching of chemical elements and compounds from soil is mainly determined by the hydrothermal mode and their content in soil (Čiuberkienė, 1999; Šileika et al., 1998). When flushing mode is prevailing in soils, water leakage profile is quite significant and depends on rainfall, plants and evaporation. When crop rotations are properly applied, after 5 years of stabilization of this agro-ecosystem, the productivity increases (Bate et al., 1993).

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Research objective - estimation of nitrogen circulation in cropping systems, applying different systems of agricultural intensity

Materials and Methods

The research was carried out in 2006-2008 in Middle Lithuania lowland, Kėdainių r., Juodkiškis village. Soil of the subject of research - Endocalcari Endohypogleyic Cambisol (CMg-n-w-can), sandy

loam.The test area (1.21 ha) dewatered by drainage, with drain spacing of 15 m and drainage depth of 1.2 m. The variants of each test with 3 repetitions are fitted on individual drains, the drain spacings of which are delimited by polyethylene panels to prevent leakage of plant nutrients from one system to another. The subject of research consists of 3 cropping systems: I - an organic one (no mineral fertilizers and pesticides are used, fertilized with manure), II - organic-mineral (with manure and mineral fertilizers in order to get the intended yield, using pesticides), III - a mineral cropping system (only with mineral fertilizers for getting the intended yield, using pesticides) (Fig. 1).

Cultivated field plants: spring barley + undersown, perennial grasses and winter wheat. The research was started from the spring barley field. Prior beginning of the research on the plots of organic and organic-mineral agriculture, 60 and 30 tons ha^{-1} of litter cattle manure was shaken out respectively. The plots of mineral and organic-mineral are fertilized with mineral fertilizers. In the organic-mineral variant of farming in 2006 $N_{50}P_{92}K_{142}$ was scattered, and in the mineral variant - $N_{50}P_{142}K_{142}$. It should be noted that growing grass in 2007 was not fertilized. The amount of nutrients intended for them was scattered for forecrops (spring barley). In 2008 on the plots of organic-mineral and mineral farming $N_{83}P_{33}K_{33}$ kg ha^{-1} of spring barley was scattered respectively.

With relation to the texture the research ground is relatively homogeneous. Soil is rich in skeleton: approximately 8 per cent in the depth of 0-100 cm. The most abundant fraction was that of sand (2 - 0.05), which on average accounts for 75 per cent, dust (0.05 - 0.002 mm) - 16 per cent. For silt fractions (> 0.002 mm) the average is 8.0%. The research ground soil is light loam on adhesive sand.

On the research ground pH_{KCL} up to 60 cm had neutral or basic reaction (7.4 - 8.5 pH). Carbonates are found already in the depth of 0-20 cm. With the increase in soil depth, its basicity (8.0-8.7 pH) increases, too. There are 18 - 27 per cent of free carbonates.

The research ground soil had average and sufficient amount of phosphorus, high potassium level - respectively 180-260 mg kg^{-1}. Total amount of nitrogen and humus in soil varies slightly more. While under organic agriculture conditions they are found in amount of 0.18 and 1.95 per cent, under intensive farming conditions the amount decreases by 28 and 15 per cent (respectively up to 0.13 and 1.65%). It should be noted that in deeper layers (60 cm) phosphorus, potassium and humus content in soil is relatively high - respectively 70 - 110, 80-216 mg kg^{-1} and 0.94 - 1.91%

In all variants of farming a normal agricultural tillage was applied. The cultures that were grown: spring barley (Hordeum Sativum) 'Ūla' and perennial grasses, red clover (Trifolium pratense) 'Liepsna' (Flame) and timothy (Phleum pratense), 'Gintaras II' (Amber), as well as spring wheat (Triticum aestivum) 'Nandu'. Total hydrothermal coefficient of field plants in growing seasons (HTC) for barley was 0.91 (optimum moisture), and in 2007 during growing season perennial grasses of the first harvest had 1.83 (excess moisture), aftermath - 1.62 (excess moisture). The HTC of spring wheat grown in 2008 was 1.29 (optimal moisture).

Drainage run-off was measured by volumetric method every 3 days; daily run-off was calculated by linear interpolation. Water samples for analyses were taken once a month. From the average values of monthly concentration and monthly runoff - monthly

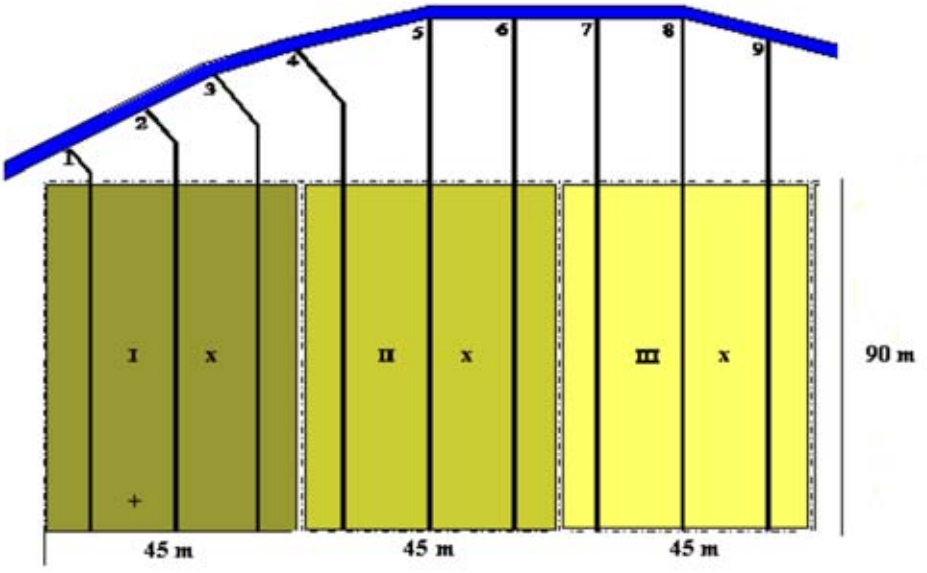

Figure 1. Scheme of the proving ground.

leaching and average annual concentration were calculated. Drainage run-off (mm) is calculated from the formula $N \equiv \frac{QxT}{F}$, where Q - flow rate l s^{-1}; T - duration s; F - area in hectares.

NH_4^+-N, NO_3^--N and total N concentration were determined colorimetrically using analyzer "FIA Star 5012 system", NH_4^+-N - using a gas diffusion analyzer, total N (after mineralization of organics with potassium persulphate) and NO_3^--N - using cadmic restoration methods (Unified effluent..., 1999).

To evaluate soil characteristics at the beginning of research, on each field two dredging holes were dug (soil profiles) and samples for laboratory analyses were taken. The texture was identified by Kaczynski pipette method, total nitrogen content - by Kjeldahl method, humus content - by Tiurin method, pH_{KCl} - by potentiometric method, carbonates in soil material - by calcimeter method. The afield occurrence depth of carbon-bearing soil was determined with 10 per cent HCl.

The samples of soil mineral nitrogen are taken 2 times a year: in the spring, before sowing and in the autumn - after harvesting. In each variant 3 joint samples were taken (every 20 cm, up to the depth of 1 m). Every 20 cm, up to the depth of 1 m), evaluating soil moisture. Mobile P_2O_5 and K_2O were determined using A-L method. Every spring, total nitrogen and humus content in the samples was determined.

After taking in the harvest from the fields of accounting, the main production yield was calculated, in 4 repetitions. Grass samples as a pinch of grass from 10-15 places were taken during harvesting. Plant biomass was dried in thermostats to get a completely dry matter, and he total energy yield of plants was calculated (Jankauskas et al., 2000).

Vegetable production in the samples was dried at +105 °C, the dry matter content was determined and NPK analyses conducted from one extract prepared by burning with concentrated H_2SO_4, hydrogen peroxide and Se catalyst. Total nitrogen in the extract was determined through distillation, potassium - using a flame photometer, phosphorus - using an ammonium-vanadium colorimetry method.

The data were processed by methods of mathematical statistics (Доспехов, 1979).

Results and Discussion

The research data show (Table 1) that the lowest nitrogen concentration and amount were in the variant, in which the organic cropping system was applied - respectively 8.23 mg kg^{-1} and 72 kg ha^{-1}.

Table 1

Average mineral nitrogen content in soil (0-60 cm)

Variants	Mineral N mg kg^{-1}	Mineral N kg ha^{-1}
I. Organic cropping system	8.23	72
II. Organic – mineral cropping system	9.52	87
III. Mineral cropping system	8.44	86

The highest mineral nitrogen content in soil was determined in the organic-mineral cropping system, mineral cropping system (respectively 9.52 mg kg^{-1} and 87 kg ha^{-1}, that is 16 and 20 per cent more, compared to the organic cropping). Under mineral cropping conditions nitrogen content in soil was 8.44 mg kg^{-1} and 86 kg ha^{-1}.

The research of average yield of field plants showed that in all cases, the most abundant yield of field plants was in the organic-mineral cropping (Table 2).

Compared to the organic cropping, the yield of spring barley grain increased by 41 per cent, that of straw - by 25 per cent. The yield of perennial grasses increased accordingly by 3, that of spring wheat grain - by 13 and the yield of straw - by 14 per cent (respectively up to 27.9; 38.0; 293; 76.6 and 66.2 GJ ha^{-1}). In applying mineral cropping the yield of field plants in many cases occupies an intermediate position between the organic and environmentally sound agriculture. After summing up the overall 3-year yields, the highest productivity was in the organic-mineral cropping system (502 GJ ha^{-1}). Under organic cropping conditions, compared to the organic-mineral, yield decreased by 8, and compared to the mineral - as much as 15 per cent (respectively up to 462 and GJ ha^{-1}). The research data for energy balance indicate (Figure 2.) that the lowest yield was in the mineral cropping system, which also had the highest energy efficiency (ETK-13). The lowest level was

Table 2

Average yield of field plants GJ ha^{-1}

Cropping system	Spring barley		Perennial grasses	Spring wheat		Total
	grain	straw		grain	straw	
Organic	19.4	30.3	286	67.9	58.0	462
Organic-mineral	27.9	38.0	293	76.6	66.2	502
Mineral	23.3	38.9	244	62.5	58.7	428

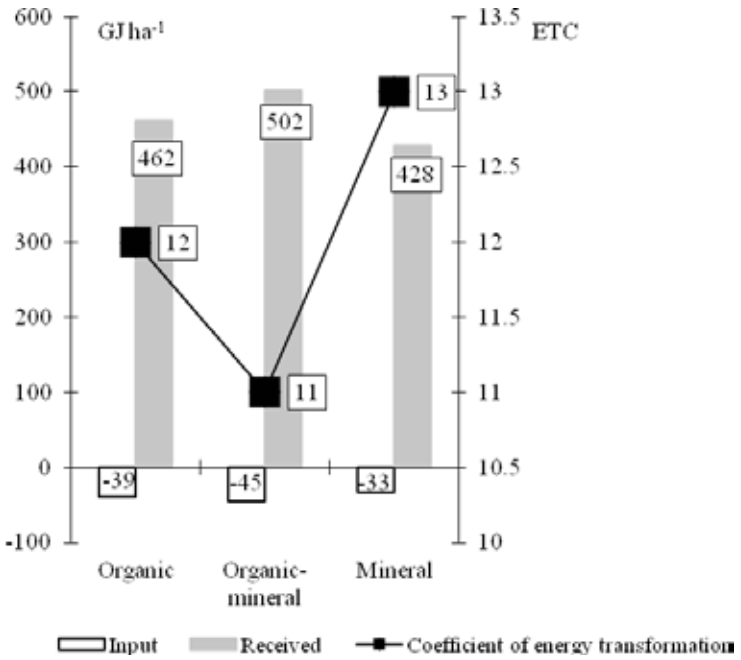

Figure 2. The influence of cropping systems on energy balance.

showed in the organic-mineral cropping system (ETC-11). In the organic cropping system energy efficiency occupied an intermediate position - 12.

Investigation of drainage water chemical composition in different cropping systems revealed that under organic and organic-mineral cropping conditions $N\text{-}NO_3^-$ concentrations were similar and amounted to 24.0 - 24.1 mg l^{-1} (Table 3). In the mineral cropping system concentration of this compound decreases by 10 per cent and amounts to 21.8 mg l^{-1}. The highest $N\text{-}NH_4^+$ concentration in drainage water was found in Variant II (the organic-mineral cropping system) - 0.031 mg l^{-1}. In the organic and mineral cropping systems concentration of this compound was 14 per cent lower: 0.026 - 0.027 mg l^{-1}. Leached plant nutrients were found mostly in the organic cropping system, where leaching was the highest in all cases compared to other cropping systems. So, under organic cropping conditions 95.0 kg ha^{-1} $N\text{-}NO_3^-$, that is 15 per cent more than in the organic-mineral and 12 percent more than in the mineral cropping system was washed out. Similar trends were also reflected in leaching data for $N\text{-}NH_4^+$.

If under organic cropping conditions, 0.14 kg ha^{-1} of $N\text{-}NH_4^+$ was leached, in the organic-mineral and intensive cropping systems it decreased by 14 per cent (to 0.12 kg ha^{-1}).

Correlation-regression analysis of the research data highlighted that N_{min} concentration in water is closely related to the yield of field plants and N_{min} in the soil (N_{min} concentration in water is closely related to the yield of field plants and N_{min} in the soil (Fig. 3). With the increase of the field plants yield, N_{min} concentration in drainage water decreases; though it increases with the increase of mineral nitrogen content. The fluctuations of N_{min} concentration in drainage water were caused by the yield of field plants at 83, and by the mineral nitrogen content in soil - at 45 percent.

Table 3

The influence of different cropping systems on chemical composition of drainage water and leaching of elements and compounds by drainage

Cropping system	mg l^{-1}			2006–2008 sum kg ha^{-1}		
	$N\text{-}NO_3^-$	$N\text{-}NH_4^+$	N_{min}	$N\text{-}NO_3^-$	$N\text{-}NH_4^+$	N_{min}
Organic	24.0	0.026	24.0	95.0	0.14	95.0
Organic-mineral	24.1	0.031	24.1	82.5	0.12	82.6
Mineral	21.8	0.027	21.8	84.7	0.12	84.8
LSD_{05}	0.8	0.03	0.9	14	0.05	14

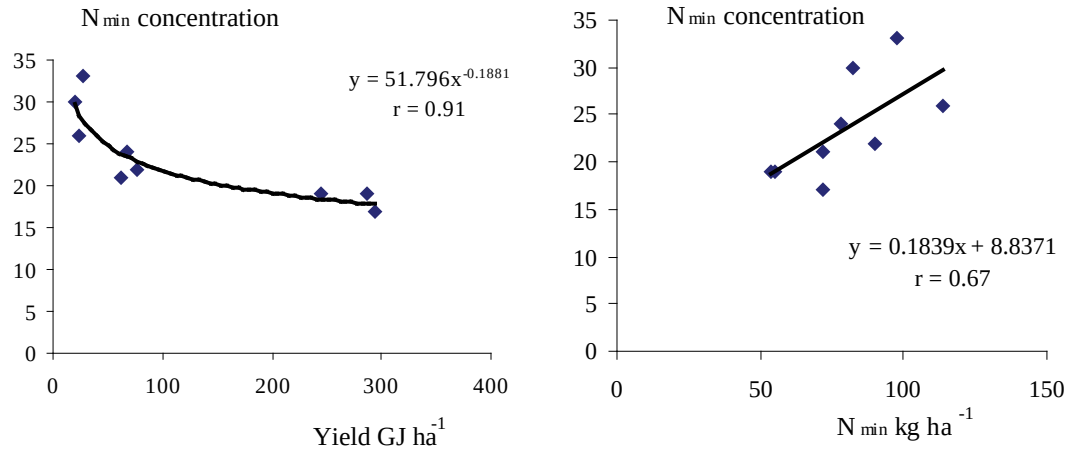

Figure 3. The dependence of Nmin conventration in drainage water (y) on field cfrop productivity (GJ ha^{-1}) and amount of mineral nitrogen in soil.

Conclusions

In 2006-2008 the agricultural research of different intensity was carried out by ASU WRI in Endocalcari Endohypogleyic Cambosol sandy loam soil (CMg-n-w-can) on the grounds of Juodkiškis village, which allows making the following conclusions:

1. The organic cropping system showed the lowest N_{min} concentration and content in soil. The highest concentration of this element was in the organic-mineral cropping system.
2. The minimum total yield of field plants was in the mineral cropping system (428 GJ ha^{-1}). In the organic cropping system this indicator increased by 8 but in the organic-mineral system - by 17 per cent. (respectively up to 462 and 502 GJ ha^{-1}). However, the mineral cropping system showed the largest energy efficiency (ETK - 13).
3. The research of nitrogen concentration in drainage water showed that the lowest content of $N\text{-}NO_3^-$ was under mineral cropping conditions (21.8 mg l^{-1}). In the organic-mineral and organic cropping systems nitrogen concentration increased by 11 per cent (to 24.0-24.1 mg l^{-1}). Ammonia nitrogen concentration was the lowest under organic cropping conditions. N_{min} concentration is closely related to the plants yield, with the increase of which it decreases, and to mineral nitrogen content in soil, with the increase of which N_{min} concentration increases.
4. Leaching of nitrogen compounds in all years of research was determined by drainage run-off. The organic farming system having the highest runoff also demonstrated the maximum nitrogen leaching by drainage.

References

1. Addiscott T. (1998) Farmers fertilizers and the nitrate flood. *New sciences*, pp. 50–54.
2. Bate M.T., Forster D.I. (1993) Organic agriculture in Ohajo: An economic perspective. *Production Agriculture*, Vol. 6, N. 4, pp. 536–542.
3. Berry P.M., Stockdale E.A., Sylvester –Bradley R. (2003) N, P and K budgets for crop rotations on nine organic farms un the UK. *Soil use and management*, Vol. 19, Iss. 2, pp. 112–118.
4. Bučienė A., Eidukevičienė M., Gužys S., Bundinienė O. (1999) Tausojančios žemdirbystės perspektyvos įvairaus našumo dirvožemiuose. (The perspectives of sparing agriculture in various productivity soils). Mokslinės konferencijos "Lietuvos integracija į Europos Sąjungą: žemės ūkio uždaviniai ir mokslo vaidmuo" pranešimai, Vilnius, pp. 117–125. (in Lithuanian).
5. Čiuberkienė D., Ežerinskas V. (1999) Agrocheminių rodiklių ir maisto medžiagų migracijos kitimai įvairiai kalkintame ir tręštame dirvožemyje. (The changes of agrochemical properties and nutrient migration soil differing in fertilization and liming). *Žemdirbystė*, t. 71, pp. 32–48. (in Lithuanian).
6. De Jager A., Onduru D., Van Wijk M.S., Vlaming J., Gachini G.N. (2001) Assesing sustainability of low-external-input farm management systems with the nutrient monitoring approach: a case study in Kenya. *Agricultural systems*, Vol. 69, Iss. 1–2, pp. 99–118.
7. Gužys S. (1999) *Žemės ūkio augalų derliaus ryšio su žemdirbystės sistemomis, dirvožemio ir vandens rodikliais analizė. (*The analysis of connection of field crop yield with cropping systems, as well as soil and water indexes). daktaro disertacijos santrauka. Akademija, 24 p. (in Lithuanian).

8. Haas G., Berg M., Kopke U. (2002) Nitrate leaching: comparing conventional, integrated and organic agricultural production systems. *International conference of agricultural effects on ground and surface waters*, Iss. 273, pp. 131–136.
9. Jankauskas B., Jankauskienė G., Švedas A. (1999) Derliaus energetinio įvertinimo patikslinimas. (The specification of yield energy estimation). *Žemdirbystės instituto užbaigtų tiriamųjų darbų konferencijos pranešimai*, Akademija, t. 31, pp. 63–65. (in Lithuanian).
10. Jankauskaitė M. (1993) Geosistemų jautrumo cheminiam poveikiui vertinimas. (The estimation of geosystems on chemical impact). *Geografija*, t. 29, pp. 78–84. (in Lithuanian).
11. Klimas A., Babenskas A. (1993) Regional impact of agriculture on groundwater quality. In: *Farming and water quality*: Proceeding of international scientific conference, Kaunas, pp. 39–41.
12. 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*, Vol. 67, pp. 161–173.
13. Olesen J.E., Ramussen I.A., Askegaard M., Kristensen K. (2002) Whole – rotation and nitrogen grain yields from the first course of an organic farming crop rotation experiment. *Agronomy*, Vol. 139, pp. 361–370.
14. Pauliukevičius H. (2000) Žemės naudmenų transformacijų poveikis azoto ir fosforo koncentracijoms upių vandenyje. (The influence of land transformation on concentrations of nitrogen and phosphorus in river water). *Vandens ūkio inžinerija*, t. 13(35), pp. 24–30. (in Lithuanian).
15. Smith I. (1989) Low input agriculture under funded or overpromoted. *American fruit grower*, Vol. 109, pp. 86–97.
16. Šileika A.S., Gaigalis K., Milius P., Kutra G. (1998) Vandenų užterštumo cheminėmis medžiagomis tyrimai Graisupio up. baseine. (The investigations of water impurity by chemical compounds in basin of river Graisupis). *Vandens ūkio inžinerija*, t. 5(27), pp. 14–26. (in Lithuanian).
17. Švedas A. (1997) Lietuvos klimato potencialo panaudojimo perspektyva. (The perspective of usage of climate potential in Lithuania). Iš: *Lietuvos klimato ir dirvožemio potencialo racionalaus naudojimo perspektyvos.* Dotnuva – Akademija, pp. 19–25. (in Lithuanian).
18. Švedas A., Šleinys R., Ežerinskas V. (2001) Augalų maisto medžiagų išplovimas. (Nutrient leaching). Iš *Lietuvos dirvožemiai*. Vilnius, 1238 p. (in Lithuanian).
19. Švedas A., Tarakanovas P. (2000) *Tręšimo planavimas*. (The planning of fertilization). Akademija, 36 p. (in Lithuanian).
20. Tyla A., Rimšelis J., Šleinys R. (1997) Augalų maisto medžiagų išplovimas iš įvairių dirvožemių. (Nutrient leaching from various soils). Dotnuva – Akademija, 25 p. (in Lithuanian).
21. Unifikuoti nuotekų ir paviršinių vandenų kokybės tyrimų metodai. (The unifying methods of quality investigations of outflow and surface waters). (1999) Vilnius, 224 p. (in Lithuanian).
22. Ботомазов Н.П., Шильников И.А., Солдатов С.М. (1993) Потери биогенных элементов с инфилтрационнами водами из выщелоченных черноземов в модельном опыте. (The losses of biogenic elements from degrade chernozem in model trial). *Агрохимия*, No 9, с. 61–68. (in Russian).
23. Доспехов Б.А. (1979) *Методика полевово опыта*. (Methodology of field trial). Москва, 416 с. (in Russian).
24. Фортескью Дж. (1985) *Геохимия окружающей среды*. (Geochemistry of surrounding environment). Москва, 360 с. (in Russian)
25. Коротков А.А., Буркова О.А. (1994) Вымывание элементов питания из дерново – подзолистых почв суходольново луга. (Leaching of nutrients from dernovo – podzolistyx soils in grasslands). *Почвоведение*, No 3, с. 63–68. (in Russian).
26. Таран В.В., Папцов А.Г. (1992) *Социально – экономические и экологические аспекты формирования альтернативных систем сельского хозяйства в промышленно развитых странах*. (Social-economic and ecological aspects of formation alternative agriculture system in developed countries). Москва, 51 с. (in Russian).

RESEARCH OF NUTRIENTS MIGRATION OF SANDY SEDIMENT AERATION ZONE OF THE RIVER BANK BUFFER AREA

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Abstract
The negative impact of agricultural pollution with biogenic materials on surface water bodies is a relevant problem. This problem is addressed by limiting or prohibiting certain activities in the so called buffer areas. The biogenic materials are carried by surface or groundwater runoff. Water infiltration is influenced by the lithological composition of sediments. River basins of sandy lithological structure were selected throughout the territory of Lithuania. An installed system of lysimeters in the boreholes allowed to monitor the change of water quality of sediments over time. The migration patterns of nutrients where identified during the investigation in the spring, summer and autumn seasons.
Key words: water quality, surface water, biogenic substances, lysimetric station, soil.

Introduction

Buffer areas are widely used as an effective way to protect rivers and streams from the negative impact of agricultural pollution. As suggested in literature, results on the retention of nitrogen in river bank buffer areas are very different (Brian and Bruce, 2004), but overall up to 74.2 ± 4.0% of nitrogen compounds can be retained in the water flowing through the river bank ecosystem. In river bank buffer areas, nitrogen retention occurs in incoming surface water flow and subsoil underground water flow. Comparison of the surface and subsoil retention efficiency reveals that the average rate of retention of nitrogen compounds in ground water is 89.6 ± 1.8%, and only 33.3 ± 7.7% in surface water. In addition, the nitrogen retention efficiency in subsoil water flow — contrary to the surface water flow — does not depend on the width of a buffer area. Most transformations of nitrogen compounds take place in the subsoil water layer. Moreover, the nitrogen removal efficiency in river bank buffer areas planted with trees can change due to features, which do not depend on the width of buffer areas, i.e. nitrogen load in the basin, soil hydraulic conductivity and the depth of a conducting layer (Pinay and Decamps, 1988; Pinay et al., 1993; Sabater et al., 2003).

Infiltration features of surface sediments are an important indicator that determines underground water resources. Large-scale (1:10 000) lithological and soil maps are suitable for assessment of sediments. Precipitation infiltration conditions are determined by the horizontal and vertical surface diffusion of the river basin. One of the most important surface diffusion indicators that influences precipitation infiltration is a surface slope. Even a slight surface inclination leads to a direct rapid runoff of precipitation water down the slope or its lower infiltration. Nitrogen and phosphorus compounds are the main background elements for the anthropogenic pollution. Nitrogen compounds are one of the most widespread in nature as well as the main element for plant nutrition; however, its surplus is detrimental to the environment. Environmentally, the most dangerous form of nitrogen is nitrates (NO_3^-), which unlike ammonium (NH_4^+), are not absorbed by soil and are less collected by plants, thus migrate in the biosphere. About 90 – 98% of nitrogen leached from soil is in the form of nitrates. In addition, some of the nitrates become harmful nitrites (NO_2^-). In Lithuanian conditions, NO_3^- concentration in soil water depends on soil features, fertilization and precipitation. Increased use of soil humus and nitrogen fertilisers raised the concentration of NO_3^- in lysimetric waters. It also increased at a low water infiltration (Adomaitis et al., 2004).

Phosphorus migrates slightly in soil and sediments. There are significant resources of agile phosphorus in the arable layer of soil, with the most concentrations in the root mass of plants. Numerous studies (Tripolskaja, 2004; Saarijärvi et al., 2004; Cermak and Klement, 2005; Ulén and Jakobsson, 2005) indicate that phosphorus compounds migrate slowly in soil; therefore, the leaching of phosphorus is negligible and amounts only up to 1–1.5 kg ha^{-1}.

Long-term researches indicate that intense processes of mineralisation within soil of light granulometric composition as well as heavy precipitation promote leaching of nitrogen to deeper soil layers; besides, migration of this element in the soil profile is strongly dependent on the vegetative cover and types of plant fertilisers as well as forms of nitrogen produced during decomposition of organic fertilisers (Tripolskaja, 2004). Concentration of nitrates in lysimetric water mostly depends on the amount of scattered nitrogen fertilisers and decomposing green manure (Krysanova, 2002; Kyllmar et al., 2006). Agricultural chemicals are the main source of the majority of biogenic substances that are found in underground water. Change in the amounts of nitrates first of all depends on use of manure and fertilisers. In damp horizons, nitrates disappear over a certain

period of time due to denitrification (Denver et al., 2009).

While migrating, nitrogen compounds can pollute larger water bodies (Bagdžiūnaitė-Litvinaitienė, 2005; Lebedynets et al., 2005), thus explicit regulation on use and storage of nitrogen is defined in the areas of agriculture and environmental protection.

This research aims to ascertain consistent patterns in migration of biogenic substances within the aeration zone of sand sediments in banks of Lithuanian rivers.

Materials and Methods

Two sandy river banks of basins with typical sand lithology structure were chosen for the research (Fig. 1). These two basins were chosen subsequently for analysis of lithology structures of 17 basins of Lithuanian rivers (Litvinaitis, 2010; 2011a). The lithologic factor of basins was estimated and research sites were chosen with the help of maps of Lithuanian Quaternary and rivers (M1:50000) and ArcGis software. Later, research sites were specified according to data of core samples taken from river banks.

The authors state that the main migration of nitrogen and phosphorus occurs by water, which filters through sediments; meanwhile transformations depend on the amount of oxygen and acidity within the environment. All these parameters can be assessed in a borehole. The lysimetric type of a borehole was chosen for the empiric groundwater level and quality analyses. This choice was influenced by the following reasons:

1) during the installation process, the deformation of the natural status of sediments and underground water is minimal;

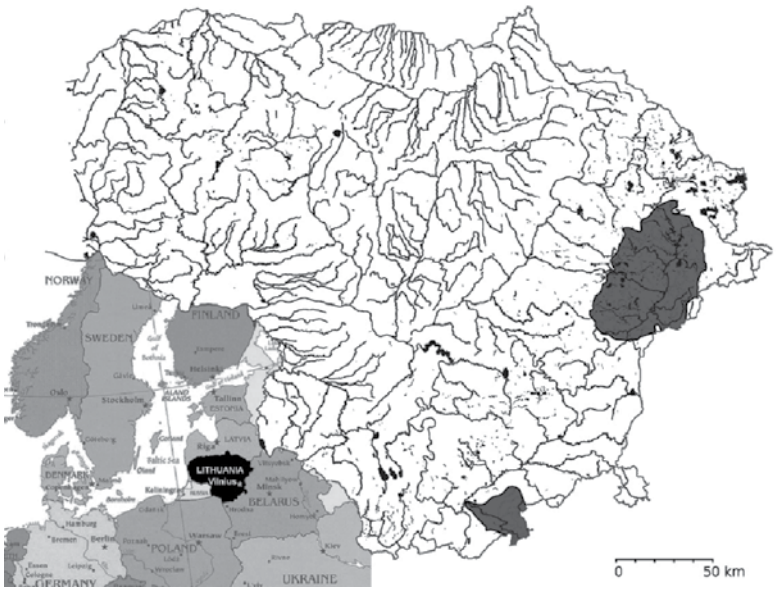


Figure 1. Basins of studied rivers.

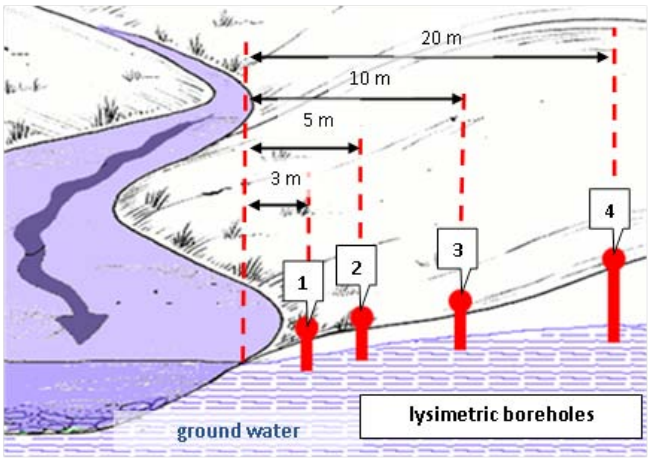


Figure 2. Situation of lysimetric boreholes on the bank of the river.

2) unified monitoring conditions are created regardless the unconfined groundwater depth;
3) maximum depth is reached using simple technical tools and low physical effort.

At research sites, boreholes were positioned perpendicularly to the river bank and at a 3, 5, 10 and 20 metre distance away from the river bank (Fig. 2).

Boreholes were installed during the period of the least discharge of stream, when water is at its lowest level. This level of water in the river was registered and named the conditional water-level (CWL), which was considered in further calculations. Boreholes were drilled down to the surface of ground water to facilitate sampling of the top layer horizon of ground water. To collect samples of water that filters down through the aeration zone, lysimeters were installed in boreholes (Litvinaitis, 2011a). Initial lysimeter reservoirs were installed at 0.1 m depth from the ground surface with others following with every meter down to the surface of ground water. At the deepest point, an additional reservoir was installed above the ground water level, increasing the frequency of the observation profile by 0.5 m. For laboratory tests, infiltration from reservoirs was sampled twice in each — spring, summer and autumn — of the researched seasons. Before taking water for samples, a reservoir was emptied and a sample of incoming fresh water was taken. The following parameters were analyzed in the laboratory: ammonium, nitrates, nitrites, phosphates, pH and the amount of water in the filtrate. The monitoring took place in spring, summer and autumn seasons of 2010–2011.

Modeling software CHEMFLO-2000 was used for graphic illustration of the results (Chemflo-2000…). The following differential equations were used to describe migration of water and chemical substances. The partial differential equation was used to describe the one-dimensional water movement.

$$\frac{\partial Q}{\partial t} = \frac{\partial}{\partial x}\left[K(h)\left(\frac{\partial h}{\partial x} - \sin(A)\right)\right]$$

where $Q=Q(h)$ is the volumetric water content; $h=h\ (x,t)$ is the matric potential; x – is the position coordinate parallel to the direction of flow; t – time; $sin(A)$ is the sine of the angle A between the direction of flow and the horizontal direction; $K(h)$ is the hydraulic conductivity of the soil at matric potential h.

Movement and degradation of chemicals in this model is described by the convection–-dispersion equation.

$$\frac{\partial}{\partial t}(Qc + \rho S) = \frac{\partial}{\partial x}\left(QD\frac{\partial c}{\partial x} - \mathrm{qc}\right) - \alpha Qc - \rho\beta A + \gamma Q$$

where $c=c(x, t)$ is the concentration of a chemical in the liquid phase; $S=S(x, t)$ is the concentration of the chemical in the solid phase; $D=D(x, t)$ is the dispersion coefficient; $Q = Q(x,t)$ is the volumetric water content; $q=q(x, t)$ is the flux of water; $\rho=\rho(x)$ is the soil bulk density; $\alpha=\alpha(x)$ is the first-order degradation rate constant in the liquid phase; $\beta=\beta(x)$ is the first-order degradation rate constant in the solid phase; $\gamma=\gamma(x)$ is the zero-order production rate constant in the liquid phase. Here α, β and γ are zero or greater.

Results and Discussion

From geomorphological point of view, the selected research site in the Ūla River basin is a plain attributed to the micro-region of Zervynos dune massif, which is located in Dainava mezzo-region of the south-eastern macro-region of Lithuania, in the area of fluvioglacial plains that were formed during the last glacial period. The type of relief – a fluvioglacial plain with an accumulative slope. Alluvium of fine sand from the Holocene lies up to 10 m from the bank and gradually changes into eolic fine sand formations.

The research site was established on the right bank of the river, in a meadow, the higher end of which is overgrown with shrubs. At a distance of 30 m, there is a slope overgrown with coniferous wood.

The firs borehole was established 3 meters away from water and 42 cm above the CWL. The investigated vertical is covered in Fluvisol, which rests on sediments of fine sand alluvium at a 62 cm depth. During the period of the research, the level of ground water was 1–2 cm higher that the level of water in the river. The borehole was equipped with a lysimeter to collect samples from the surface and at a depth of 40 cm. The second borehole was established 5 m away from the river and 52 cm above the CWL. Here, a 30 cm thick layer of Fluvisol rests on sediments of fine sand alluvium. During the period of the research, the level of ground water was 3–5 cm higher that the level of water in the river. The borehole was equipped with a lysimeter to collect samples at 10 cm (surface) and 50 cm of depth. At 10 m distance from the bank, the surface of the soil is 85 cm higher than the CWL. Here, an approx. 25 cm thick layer of Arenosol-type soil rests on sediments of fine sand eolic formations. During the research period, the amplitude of ground water fluctuations amounted to 18 cm and was the greatest at this point in the research site. A lysimeter was installed to collect samples from the surface and

at a depth of 1 meter. The fourth borehole, which was drilled at the point farthest away from the river, was 143 cm above the CWL. Just as in the case with the third borehole, an approx. 25 cm thick layer of Arenosol-type soil rests on sediments of fine sand eolic formations. Contrary to the data of the third borehole, the level of ground water in the fourth borehole was hardly changing and remained within the amplitude of 5 cm. A lysimeter was installed to collect samples from the surface and at depths of 1, 1.5 and 2 meters.

Geomorphologically, the research site in the Žeimena River basin is located in the section of valleys attributed to the junction of rivers Žeimena and Neris, which is situated in the mezzo-region of Žeimena plain of the macro-region of the north-eastern plain, in the area of fluvioglacial plains that were formed during the last glacial period. The site has the fluvial relief particular to river valleys of the Holocene and Late Glacial periods. Fine sand alluvium of the Holocene lies at the depth of 5 m, gradually changing into medium sand fluvioglacial sediments.

The research site was established at the right bank of the river, in a meadow of a littoral coniferous wood, which is situated perpendicularly to and at a 50 m distance away from the river bank.

The surface of the first borehole is located 32 cm above the CWL. A 15 cm layer of Halpic Arenosol covers alluvial medium sand sediments; a layer of gravel was found at a 48 cm depth. During the period of the research, the level of ground water was 1–2 cm higher that the level of water in the river. A borehole was equipped with a lysimeter to collect samples from the surface and the depth of 40 cm. The second borehole was drilled to 42 cm above the CWL. Medium sand sediments were found under Arenosol (20 cm). Deeper, at a 40 cm depth, gravel was found. The level of ground water fluctuated in the same way as in the first borehole. The second borehole was equipped with a lysimeter to collect samples from the surface and the depth of 0.5 m. The third borehole was drilled at 138 cm above CWL; here, a 25 cm thick layer of Arenosol covers homogeneous medium sand sediments found along the entire analysed vertical. The level of ground water, which was 5 cm higher if calculated from the actual level of the river, changed to 3 cm during the research. The borehole was equipped with a lysimeter to collect samples from the surface and at depths of 1 and 1.5 m. The fourth borehole was drilled to 164 cm above the CWL. Here, just as in the third borehole, a layer of Arenosol was found up to 25 cm of depth with deeper lurking homogeneous layer of medium sand. In comparison to piesometric indications of the third borehole, the average level of ground water is lower; however, fluctuation amplitude was greater by 3 cm.

At the research site by the Žeimena River, concentrations of ammonium ions (NH_4^+) were equally distributed over all research seasons. Greater concentrations of ammonium were registered in the first and the second lysimeters amounting from 0.64–1.28 mg l^{-1} at the surface to 0.26–1.15 mg l^{-1} in the ground water. Lower concentrations were found in the 3rd and the 4th lysimeters, amounting from 0.02–0.46 mg l^{-1} at the surface to 0.01–0.23 mg l^{-1} 1 at a depth of one meter and up to 1.19 mg l^{-1} in ground water. During all seasons, reduction in concentrations of ammonium ions in the depth of up to 1 m was influenced by nitrification processes and assimilation of ammonium ions by plants. On the average, reduction amounted to 1.3% during spring, 1.5% during summer, and 1.7% during autumn (Fig. 3). Increase in concentrations in the 3rd and the 4th lysimeters is related to denitrification processes and change in the level of ground water.

At the research site by the Ūla River, ammonium concentrations were gradually decreasing with depth: greater concentrations were registered in summer, reducing with depth by 1.2–1.7 times on the average from 0.47–1.29 mg l^{-1} at the surface and to 0.02–0.84 in ground water; lower concentrations were registered in spring, reducing with depth by 1.7–27 times on the average from 0.27–0.77 mg l^{-1} at the surface and to 0.02–0.24 mg l^{-1} in ground water; and in autumn, concentrations reducing by 29–33 times from 0.20–0.82 mg l^{-1} at the surface to 0.02–0.24 mg l^{-1} in ground water (Fig. 4).

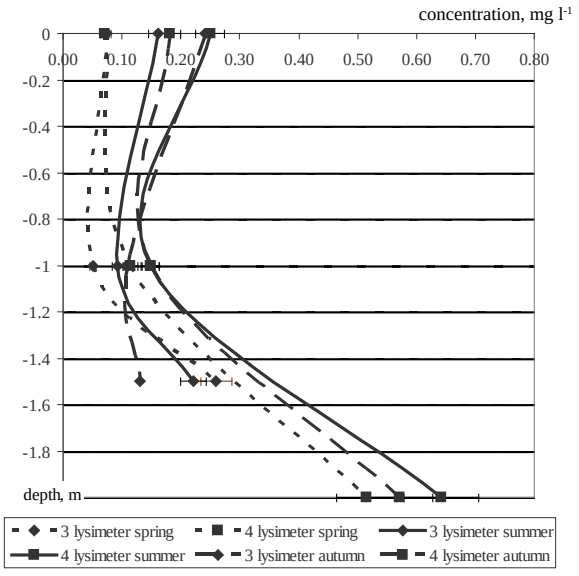


Figure 3. Change in ammonium ions depending on a season. Žeimena River bank.

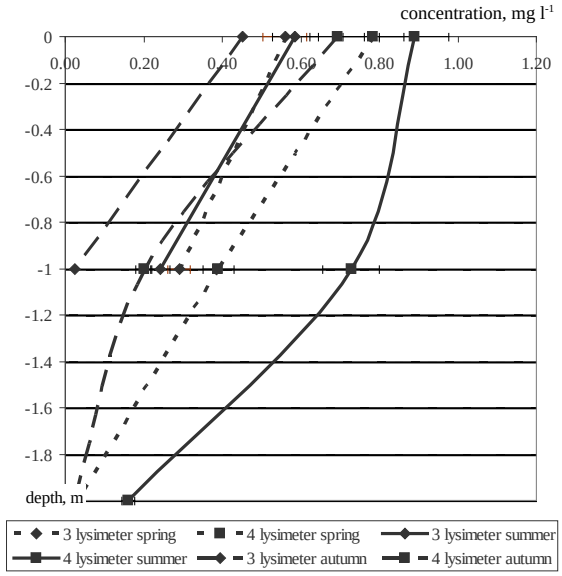
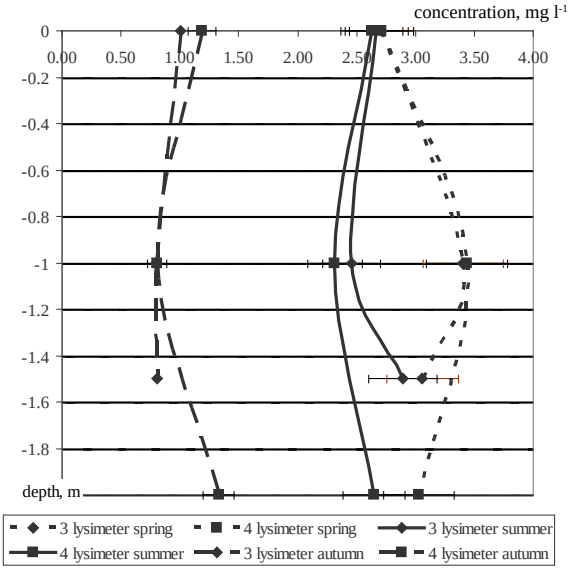


Figure 4. Change in ammonium ions depending on a season. Ūla River bank.

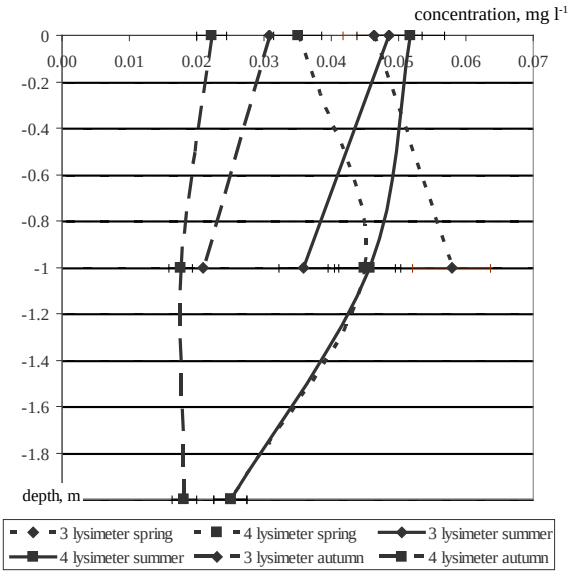
Concentration of ammonium ions decreases as a direct proportion of increasing infiltration coefficient. This was ascertained subsequently to analysis of precipitation and evaluation of types of sediments from research sites on the basis of infiltration indicators.

At the research site by the Žeimena River, concentrations of nitrate ions (NO_3^-) varied from 0 to 3.55 mg l^{-1}. The greatest values of concentrations were registered in seasons of spring with 0.91–3.55 mg l^{-1} and summer 0.25–3.49 mg l^{-1}; and the least – in autumn with 0–1.80 mg l^{-1}. At the research site by the Ūla River, concentrations of nitrate ions varied from 0 to 0.11 mg l^{-1}. The greatest values of concentrations were registered in the season of summer with 0.01–0.11 mg l^{-1}; and the least – in spring with 0.02–0.08 mg l^{-1} and autumn with 0.01–0.04 mg l^{-1}.

At the research site by the Žeimena River, 10 m away from the river bank, reduction in concentrations of nitrate ions were registered both on the surface and in ground water during all seasons. The distribution of the variation was as follows: approx. 1.8 times in summer and spring seasons, and 3.5 times in summer. At the research site by the Ūla River, this consistent pattern was found in the season of summer with concentrations dropping by approx. 1.2 times. During spring season, the consistent pattern was found in relation to migration of nitrates by water from melting soil frost and snow. As sources of nitrates, fallen leaves and decomposing grasses are washed by the surface runoff; and once soil frost melts, they are washed deeper into sediments. This can be proved by a vertical analysis of the profile. In spring, concentrations of nitrates increase by 27% in the layer of up to 1 m deep at the research sites by both rivers. Considering infiltration indicators and times soil frost melted as well as investigation times, it was identified that nitrates that accumulate over winter can lurk at a depth of 0.9–1.2 m. This confirms that at a depth greater than 1 m to the surface of ground water, the amounts of nitrates decrease by 28% (Fig. 5).



Žeimena River bank



Ūla River bank

Figure 5. Change in nitrates depending on a season.

During the summer season, processes are influenced by vegetation that assimilates a part of organic substances through roots. It was found that at

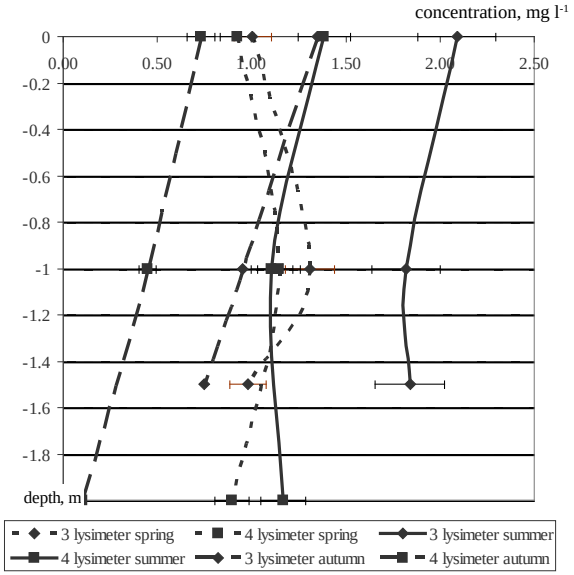
a 1 m depth, in the root zone of perennial grasses, the amount of nitrates decreased by 9% on the average. At the research site by the Ūla River, as roots of shrubs and trees that grow close to the borehole assimilate water and organic substances, the amounts of nitrates at layers deeper than 1 m were two times less.

No consistent patterns were found in changes of nitrite ions (NO_2^-) at any of the research sites. Concentrations of nitrite ions changed on the surface, amounting to 0.04–54 mg l^{-1}, and in ground water, amounting to 0.11–83 mg l^{-1}.

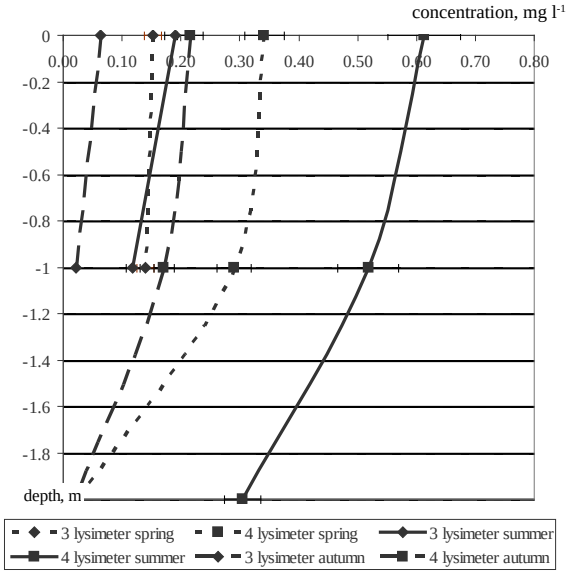
No consistent patterns were found in changes of the amount of oxygen and pH of the infiltrate at any of the research sites. pH at the Ūla research site varied within the range of 6.5–8.1%; meanwhile at the Žeimena — 6.5–7.3%, with slightly more acidic (up to 4%) profiles registered during spring. This was impacted by winter decomposition of grasses, leaves of shrubs and needles. Increase in amounts of oxygen in filtrate collected at all research sites is related with periods of greater precipitation amounting to 6–9 mm per day.

At the research site by the Žeimena River, concentrations of phosphates (PO_4^{3}) varied by 0.02–3.13 mg l^{-1} during the research period. The greatest concentrations were registered in summer with 0.86–3.13 mg l^{-1}, especially at a 10 m distance. Here, they were changing within the range of 1.98–3.13 mg l^{-1}. The least concentrations were registered in autumn with 0.02–1.43 mg l^{-1}; meanwhile in spring, concentrations of phosphates varied by 0.37–1.55 mg l^{-1}. During summer season, variation of phosphates was registered in lysimeters Nos 1–3 with 2.14–3.13 mg l^{-1} in the surface up to 1.98–2.65 mg l^{-1} in ground water; i.e. concentrations decreased by 8–17%. In the 4th lysimeter, concentrations varied from 1.40–1.73 mg l^{-1} on the surface to 1.09–1.22 mg l^{-1} at 1 m depth (reduction by 36%) and increased up to 1.50 mg l^{-1} in deeper layers.

In spring, an increase of phosphate in sediments located at depth of up to 1 m was registered in all lysimeters with 0.70–1.42 mg l^{-1} at the surface to 0.74–1.55 mg l^{-1} in ground water; and a decrease was up to 0.74–1.22 mg l^{-1} in ground water (Fig. 6). As a percentage of surface concentrations, phosphate concentrations that were greater by 11–18% were found in groundwater collected by the 1st and the 2nd lysimeters and at a 1 m depth in the 3rd lysimeter; and in ground water collected by the 3rd and the 4th lysimeters, this increase amounted to 2–15%. In autumn, concentrations decreased in the 3rd and the 4th lysimeters from 1.46–1.43 mg l^{-1} on the surface to 0.02-0.87 mg l^{-1} in ground water.



Žeimena River bank



Ūla River bank

Figure 6. Change in phosphates depending on a season.

At the research site by the Ūla River, concentrations of phosphates varied within the range of 0.01–0.94 mg l^{-1}. The greatest concentrations were registered in summer with 0.02–0.94 mg l^{-1}; and lower – in spring, with 0.02–0.54 mg l^{-1}, and in autumn, with 0.01–0.40 mg l^{-1}. Deeper down, decrease in concentrations of phosphates were registered in summer and autumn seasons. In summer, concentrations of phosphates decreased

by 1.9–7.1 times from 0.12–0.20 mg l^{-1} on the surface and up to 0.02–0.10 mg l^{-1} in groundwater collected by lysimeters Nos 1–3, and from 0.42–0.54 mg l^{-1} to 0.02–0.03 mg l^{-1} in the 4th lysimeter with concentrations of phosphates from the surface to the ground water reducing by 22 times. In autumn season, all lysimeters registered a reduction in concentrations by 1.3–12 times from 0.03–0.17 mg l^{-1} on the surface to 0.01–0.11 mg l^{-1} in ground water. In spring, increase in phosphates was registered in lysimeters Nos 1–3 from 0.05–0.24 mg l^{-1} on the surface to 0.04–0.22 mg l^{-1} in ground water, with increase of phosphates in ground water amounting to 1.4 times if compared to the surface water. In the 4th lysimeter, concentration of phosphates decreased by 1.7 times.

Conclusions

Subsequent to research on river banks with sandy lithology, it was ascertained that reduction in concentrations of ammonium ions is directly dependent on the increase of the sediment infiltration coefficient. Variation in ion concentrations of other nitrogen compounds and phosphates depends on a season. In spring, melting snow washes nitrates down into sediments. Irrespective of the type of soil or sand sediments, amounts of nitrates at 1 m depth increases by 27%. In summer, herbaceous vegetation decreases amounts of nitrate ions by 9%. Besides, in summer season, irrespective of concentrations on the surface, amounts of phosphate ions – in the layer from the surface to 1 m in depth – reduce by 0.9 mg l^{-1}.

References

1. Adomaitis T., Vaišvila Z., Mažvila J., Griškevičienė S., Eitminavičius L. (2004) Concentration of nitrogen (NO_3^-, NH_4^+, NO_2^-) compounds in lysimeter water of a differently fertilized sandy loam soil, *Žemdirbystė: mokslo darbai*, vol. 88, pp. 21–33.
2. Bagdžiūnaitė-Litvinaitienė L. (2005) Research and assessment of changes in biogenic substances in the water of rivers, PhD thesis, Vilnius Gediminas Technical University, Vilnius, Lithuania. 133 p.
3. Brian Hm., Bruce D. (2004) A review of the efficiency of buffer strips for the maintenance and enhancement of riparian ecosystems, *Water quality research journal of Canada*, vol. 39, no 3, pp. 311–317.
4. *CHEMFLO-2000, Interactive Software for Simulating Water and Chemical Movement in Unsaturated Soils*. Publ. No. EPA/600/R-03/008. Available at: http://www.epa.gov/ada/csmos/models/chemflo2000.html, 15 March 2012.
5. Cermak P., Klement V. (2005) Lysimeter experiments in the Chech Respublic, *Höhere Bundeslehr – und Forschungsanstalt für Landwirtschaft, Gumpensteiner Lysimetertagung*, vol. 11, pp. 153–154.
6. Denver J.M., Tesoriero A.J., Barbaro J.R. (2009) Trends and Transformation of Nutrients and Pesticides in a Coastal Plain Aquifer System, United States, *J. Environ. Qual.*, vol. 39, pp. 154–167.
7. Krysanova V. (2002) Assessment of nitrogen leaching from arable land in large river basins, PhD thesis, Potsdam Institute for Climate Impact Research, Telegrafenberg, Germany. 124 p.
8. Kyllmar K., Carlsson C., Gustafson A., Ulen B., Johnsson H. (2006) Nutrient discharge from small agricultural catchments in Sweden. Characterisation and trends, *Agriculture, Ecosystems & Environment*, vol. 115, pp. 15–26.
9. Lebedynets M., Sprynskyy M., Kowalkowski T., Buszewski B. (2005) Evaluation of Hydrosphere State of the Dniester River Catchment, *Polish Journal of Environmental Studies*, vol. 14, pp. 70.
10. Litvinaitis A., Šaulys V. (2011) Research methodology of sediment aeration zone of the river bank buffer area, *Annual 17th International Scientific Conference Proceedings Research for Rural Development 2011*, vol.2, pp. 141–145.
11. Litvinaitis A., Šaulys V. (2011a) The influence of lithological structure on river runoff in the south-eastern Lithuanian hydrologic area, *The 8th International conference "Environmental engineering": selected papers*, vol. 2. pp. 593–598.
12. Litvinaitis A., Šaulys V., Bagdžiūnaitė-Litvinaitienė L. (2010) The influence of neogene lithology on the Lithuanian river hydrologic regime, *Annual 16th International Scientific Conference Proceedings Research for Rural Development 2010*, vol. 2, pp. 142–148.
13. Pinay G., Decamps H. (1988) The role of riparian woods in regulating nitrogen fluxes between alluvial aquifer and surface water: a conceptual model, *Regulated Rivers: Research and Management*, vol. 2, pp. 507–516.
14. Pinay G., Roques L., Fabre A. (1993) Spatial and temporal patterns of denitrification in riparian forest, *Journal of Applied Ecology*, vol. 30, pp. 581–591.
15. Sabater S., Butturini A., Clement J.C., Burt T., Dowrick D., Hefting M., Matre V., Pinay G., Postolache C., Rzepecki M., Sabater F. (2003) Nitrogen removal by riparian buffers along a European climatic gradient: patterns and factors of variation, *Ecosystems*, vol. 6, pp. 20–30.

16. Saarijärvi K., Virkajärvi P., Heinonen T.H., Taipalinen I. (2004) N and P leaching and microbial contamination from intensively managed pasture and cut sward on sandy soil in Finland, *Agriculture, Ecosystems & Environment*, vol. 104, no. 3, pp. 621–630.
17. Tripolskaja L. (2004) The effects of long -term fertilizer use on soil properties in the lysimetric stations, *Agriculture. Scientific articles*, vol. 85, no. 1, pp. 28–41.
18. Ulén B., Jakobsson C. (2005) Critical evaluation of measures to mitigate phosphorus losses from agricultural land to surface waters in Sweden, *Science of the Total Environment*, vol. 344, no. 3, pp. 37–50.

THE INFLUENCE OF DIFFERENT HUMUS LAYERS ON THE DRAINAGE RUNOFF DURING DIFFERENT SEASONS

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Abstract
Hydro-physical properties of heavy or presses soil as well as water regime may be improved by various ways, taking into account the texture of soil and climatic conditions. Drainage is the tool for productive farming and economic benefit generation. Hydrological activity of drainage typically depends on project installation quality, anthropogenic and climatic factors. It is important to assess drainage activity under different meteorological conditions. One of methods to improve drainage performance is its installation with thickened humus layer. Lithuanian soil humus layer is close to arable layer and is equal to approximately 20–25 cm. The impact of humus on heavy-textured soil is multiple, since not only moisture regimes, biological activity, sorption capacity, chemical and biological characteristics, stability of plant nutrition are related with its quantity. The dynamics of drainage activity in soil with thickened (up to 40–50 cm) humus layer and with humus layer of natural thickness (20–30 cm) during various seasons of period of 1989–2009 is reviewed. Especially important indicator of drainage functioning – water runoff dynamics. The present article analyses the variation of climatic conditions and drainage runoff in the object. It is determined that the lowest quantity of precipitation in the researched territory during the research period is in spring and winter but the highest – in summer and autumn. During the research period the highest drainage runoff in the field I was during winter season (46.3%), in the field II – in winter and spring almost the same (32–33%).
Key words: runoff, drainage, humus layer.

Introduction

Climatic conditions and physical geographic factors determine the fact that in the territory of Lithuania, there are 3.4 million hectares of too wet land or about 86% of total agricultural area, which may be used extensively and productively only after drainage (Lukianas and Ruminaitė, 2009). Climate change impact on flora receives increasing attention around the world (Fuhrer, 2003). Multi-annual sequences of air temperatures have shown the increase of temperature during all seasons, except autumn (Meilutytė-Barauskienė et al., 2008).

Drainage flow largely depends on climatic conditions, drainage level, nature of soil, plants grown, etc. When there is more precipitation and lower temperature in warm periods, runoff is higher. During cold season the runoff increases at higher temperature (Ramoška and Morkūnas, 2006). Jin et al. (2008) confirm the importance of soil temperature on drainage activity.

Precipitation distribution in a territory and their change within a year has a great impact on hydrological phenomena, soil formation and plant-growing seasons (Bukantis et al., 2009). Climate change impact on flora has increasing attention around the world (Fuhrer, 2003). Air temperature and moisture content generally determines the duration of plants vegetation and development, size of yield. The influence of meteorological conditions occurs not only directly on the yield, but also on its quality indicators (Kupčinskas et al., 2003; Šidlauskas and Švedas, 2001).

The activity of drainage systems mainly depends on materials used and installation conditions (Rimidis, 2001). One of methods to improve drainage performance – its installation with thickened humus layer. Lithuanian soil humus layer is close to arable layer and is equal to approximately 20–25 cm. (Dirsė et al., 2002). The impact of humus on soil in Lithuanian territory has been described by many authors (Maikštėnienė et al., 2007; Dirsė et al., 1992). In order to control runoff, it is necessary to know the periodicity of drainage activity, runoff and factors, which determine it.

Controlled drainage is important, seeking to control hydrological cycle and in order to use water resources (Zhonghua et al., 2006). Drainage damming by intercepting runoff may be considered as a measure, promoting the rational use of water resources and reduction of environmental impact (Morkūnas and Ramoška, 2001). Controlled drainage is recognized as an advanced management mode, limiting nitrogen and phosphorus elution from soil and its fall onto the pools of surface water (Evans et al., 1995). By controlling the intensity of drainage runoff a large part of runoff and dissolved chemical substances are intercepted (Wesstrom et al., 2001). In order to control runoff, it is necessary to know the periodicity of drainage activity, runoff and factors, which determine it. However, there is no detail analysis about relation between humus quantity and seasonal drainage runoff quantity. The mentioned analysis allows determining the impact of humus layer on drainage runoff distribution during the year and the impact of local conditions. The

results obtained are applied for solving the issues of water treatment and environmental protection. Moreover, this information is required, while adapting mathematical (stochastic) models for forecast of hydrological phenomena.

The objective of the present paper is to determine the relation between humus layer thickness and drainage runoff, measured during different years, and to assess its variability in time.

Materials and Methods

The investigation was carried out in the experimental fields of Aleksandras Stulginskis University in 1989–2009. The investigations were carried out in loamy soils as in Lithuania light loam and medium loam soils make 38.4% of farming lands. In the territory of investigations the soil was calcareus deeper gleyic leached soil, (the experimental according to FAO: calcar - HypogleyicLuvisol), according to mechanical composition – loam of medium-heaviness and light loam. Soil volume mass in the layer of 1 m varies from 1.3 to 1.7 g cm^{-3}, porosity - from 50.9 to 32.0%, hygroscopic moisture – from 0.95 to 2.36%, filtration coefficient in arable layer – 0.31–0.94 m day^{-1}.

Scheme of the experiment: 1) 1.71 ha with thickened layer of 45–50 cm (field I), 2) control, 1.72 ha with natural humus layer of 20–30 cm (field II, Fig. 1).

Drainage systems were installed in 1988. Collectors of drainage systems were laid to different wells for runoff measurement. Drainage runoff was measured by volumetric method. Meteorological conditions were assessed, following the data of Kaunas Meteorological Station, located 0.5 km from test field. The obtained results were statistically processed by Statistica 7. The obtained data were analysed using descriptive statistics and LSD analysis. The significance of the differences between the samples was assessed using ANOVA. The treatment effects were compared using the least significant difference test at the level of 95% (LSD_{05}, p=0.05) probability. Also correlation analysis was used (R).

Results and Discussion

Meteorological conditions in 1989–2009 were studied while analysing changes in seasonal distribution of the average air temperature and precipitation amount in Central Lithuania, according to data of meteorology station located in the Academy (winter XII-II, spring III-V, summer VI-VIII, autumn IX-VIII).

During the research period climatic norm (1961–1990) was more exceeded than not reached. The highest excess of climatic norm was +32% (2009) and +55% (2007) and shortage -22% (2008) and -34% (1996). During different seasons the quantity of precipitation decreased in winter and autumn (4.1mm and 1.4 m respectively in comparison with multi-annual norm). The intensity of increase was lower in autumn (4.2 mm) and the quantity of precipitation increased even by 23.8 mm in winter (during December – February). The intensity of increase was lower in autumn (4.2 mm) and the quantity of precipitation increased even by 23.8 mm in summer (Fig. 2). Correlation relation is moderate only during the summer season (R=0.48).

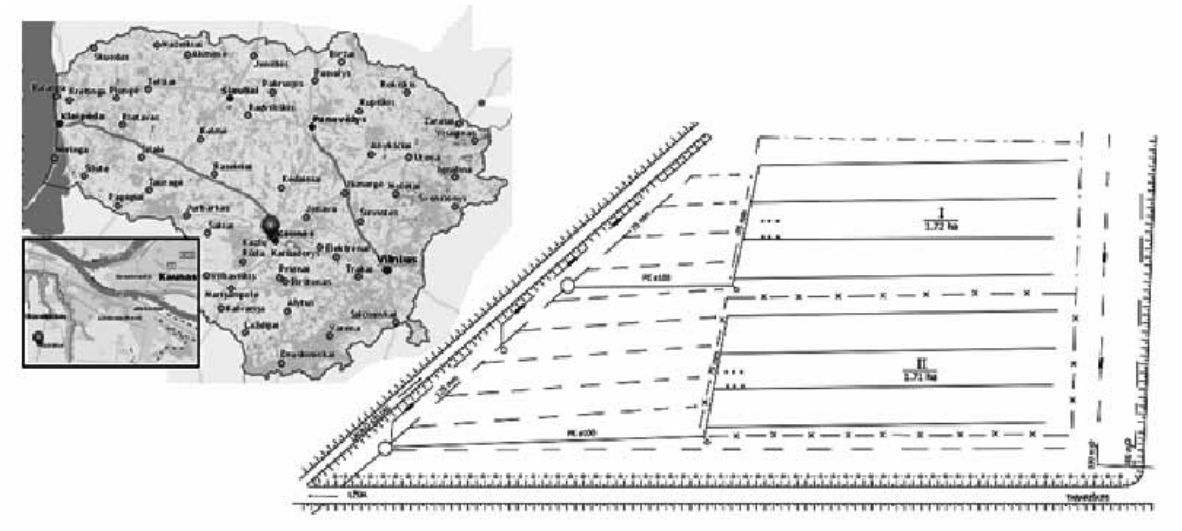

Figure 1. Study area location and scheme.

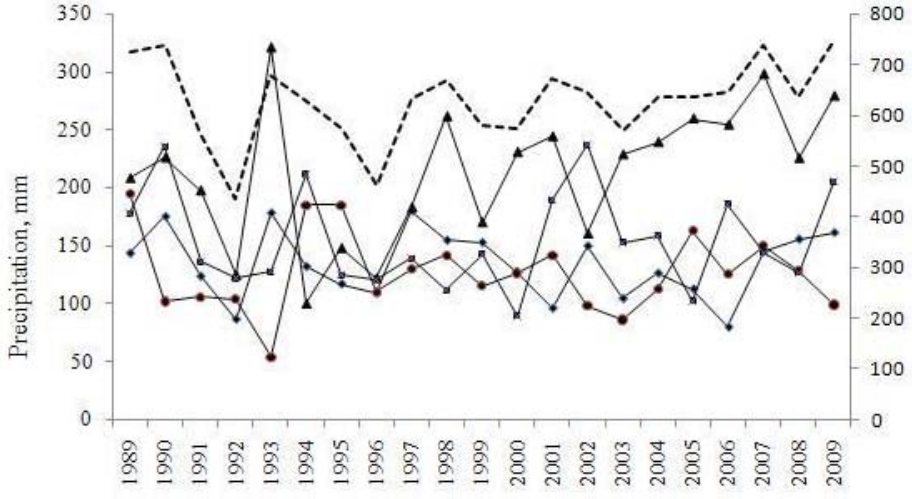

Figure 2. Average seasonal quantity of average precipitation (1989–2009) and multi-annual climatic norm (1961–2009).

Winter Spring Summer Autumn Multi-annual climatic norm

During the research period the change of average temperature was not so significant: temperature was close to climatic norm during all seasons. Average temperature of spring months is characterized by the most significant increase (0.3 °C, Fig. 3). Correlation is moderate during all seasons, thus, the increase of temperature trend is clearly observed. These results are consistent with forecasted results of global temperature increase, which state that the average temperature in 2030 should be higher by 1 °C than in the end of twentieth century, i.e., it should increase by 0.033 °C annually (Bukantis et al., 2005). Correlation relation is moderate during summer (R=0.42), winter (R=0.59) and autumn (R=0.64) seasons and strong during spring season (R=0.7).

While analysing annual drainage runoff in fields I and II (1989-2009), 30% higher drainage runoff from the field with increased humus quantity is observed. The differences were significant ($p<0.05$; Fig.4).

While analysing the data of 1989–2009 in the researched territory, it is determined that the lowest quantity of precipitation is in spring (22.2%), very similar quantity of precipitation is observed in winter (19.7%) and the highest quantity of precipitation is in summer (even 34.5%) and autumn (24.5%). During research period the drainage runoff in the

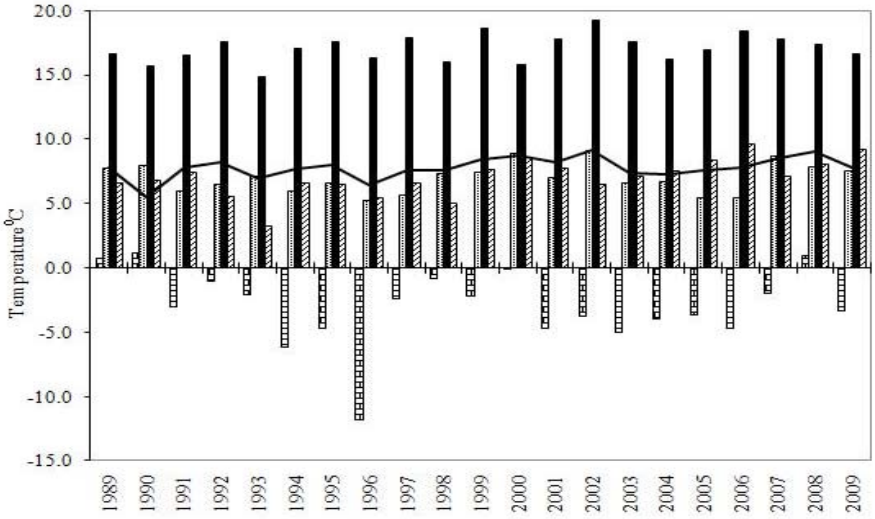

Figure 3. Average seasonal quantity of average air temperature (1989-2009) and multi-annual climatic norm (1961-2009).

Winter Spring Summer Autumn Year

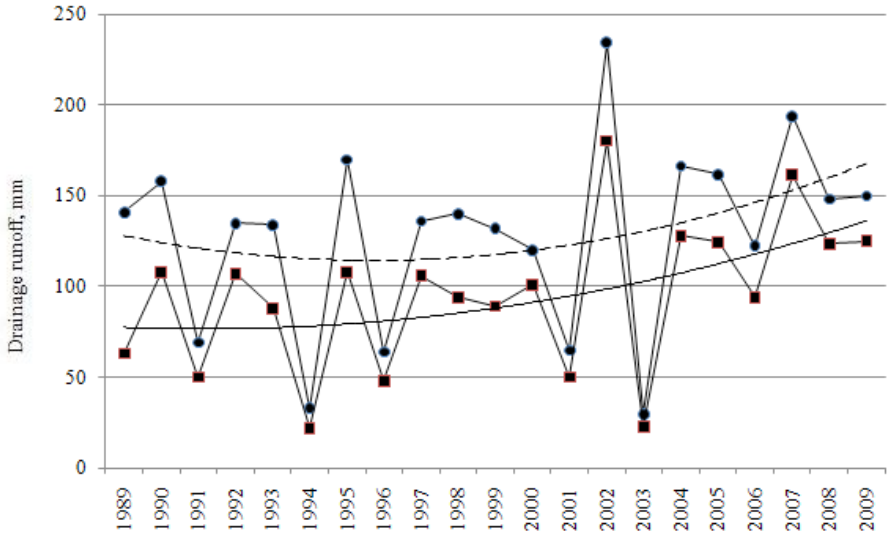

Figure 4. Chronological succession of drainage run-off and their linear fluctuation trend.
Runoff I Runoff II Poly. (Runoff I) Poly. (Runoff II)

field I was highest during winter (46.3%), in spring – 42.8% and the lowest in summer (1.6%), in the field II – the drainage runoff was almost equal in winter and spring (32–33%) and the lowest – also in summer (Fig. 5). Thus, regulated drainage may help the plants to provide with water, since they often lack moisture. After carrying out research Ramoška et al. (2006) determined that the nature of drainage activity generally had no impact on water level of soil in the gap between drains. The analysis of runoff observation data revealed that seasonality, typical for run-off change, remains: during spring – March and April – the average runoff is the highest but the lowest in the summer season – July and August, while in May, June and August – almost the same.

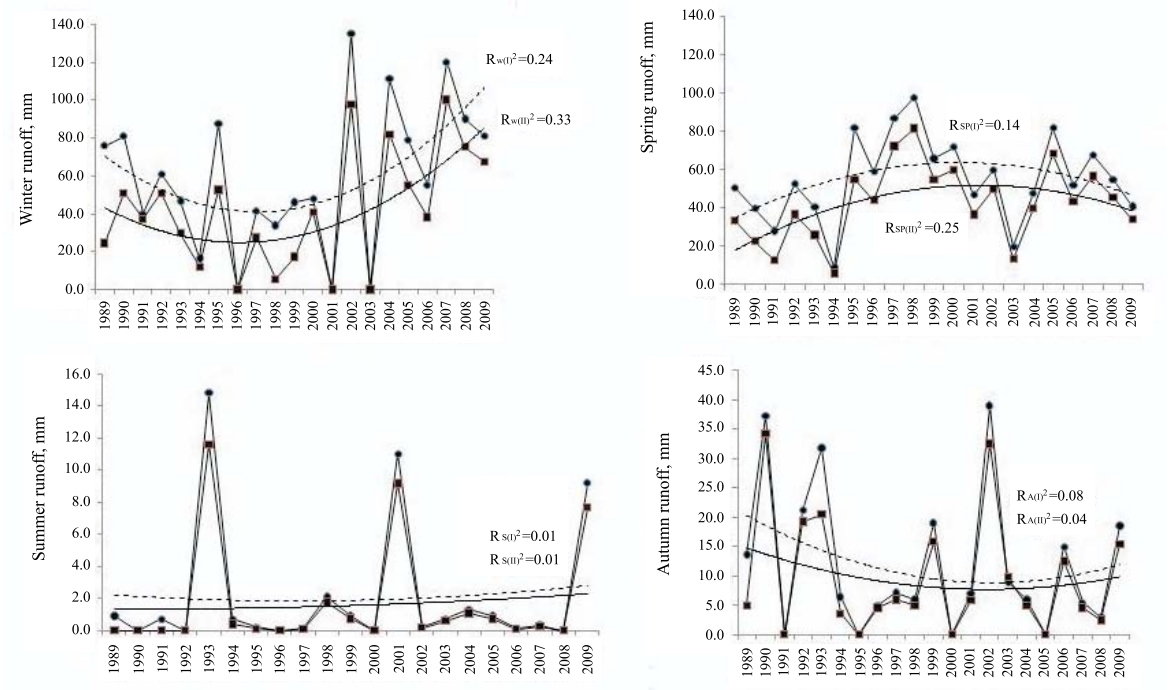

Figure 5. Dependence of humus layer in different seasons of 1989–2009 periods (R_w – winter, R_{sp} – spring, R_s - summer, R_a – autumn).
RunoffI RunoffII Poly. (RunoffI) Poly. (RunoffII)

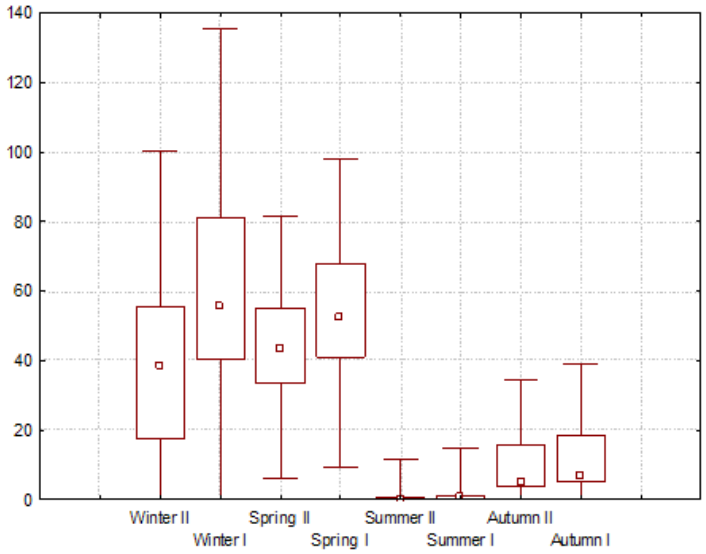

Figure 6. Drainage runoff distribution during different seasons of research period.

When studying relations between drainage runoff in different seasons it was determined that in bold thick (I) in winter there was an average link ($r=0.5$, $p<0.05$), and in other seasons – the inter-relation was weak (in spring and autumn ($r=0.4$, $r=0.3$), and very weak in summer ($r=0.1$). In natural layer (II) there was an average link in winter too ($r=0.6$, $p<0.05$) and in spring ($r=0.5$, $p<0.05$), the inter-relation was very weak in summer ($r=0.1$) and the inter-relation was weak in autumn ($r=0.3$). Tendency of trends decrease can be seen in spring in both fields. Thus, the drainage runoff in the field with thin humus layer has a greater impact compared to the one with the thickened humus layer.

The first field (the thickened humus content) drainage runoff ranged higher amplitude than the field in all seasons, with a natural layer of humus. Statistically significant results were obtained in winter and spring ($p<0.05$. Fig. 6).

Conclusions

1. In case of thickened humus layer annual drainage runoff was approximately 21% of annual precipitation quantity, when natural humus layer was approximately 16%.
2. Annual drainage runoff is higher by 31% in thickened humus layer while comparing with natural layer had significant ($p<0.05$) positive effect.
3. Increased humus quantity has statistically significantly increased the drainage runoff during winter and spring seasons ($p<0.05$).

References

1. Bukantis A., Rimkus E. (2005) Climate variability and change in Lithuania. *Acta Zoologica Lituanica* 15(2), pp. 100–104.
2. Bukantis A., Kažys J., Rimkus E. (2009) Gausus krituliai Lietuvoje 1961-2008 metais (Abundant precipitation in Lithuania in 1961-2008 year). *Geografija*, 45(1), pp. 44–53. (in Lithuanian).
3. Dirsė A. (2001) Žemės ūkio augalų vegetacijos laikotarpių drėgmingumas (Agricultural vegetation periods humidity). *Žemės ūkio moksla*, 3, pp. 51–56. (in Lithuanian).
4. Dirsė A., Galminas Z., Juodinis G. (2002) Drenažo nuotėkio priklausomybė nuo humusingo dirvožemio sluoksnio (Drainage runoff from the dependence of soil humus layer). *Žemės ūkio mokslai*, 21(43), pp. 52–56. (in Lithuanian).
5. Dirsė A., Juodinis G., Kėželis A., Kinčius L., Pocienė A. (1992) Vandens režimo reguliavimas storinant humusingą dirvožemio sluoksnį (Water regime of thickened humus soil layer). Lietuvos žemės ūkio akademijos mokslo darbai. *Žemės ūkis,* 39, pp. 8–13. (in Lithuanian).
6. Evans R.O., Skaggs R.W., Gilliam W. (1995) Controled versus conventional drainage effects on Water quality. *Journal of irrigation and drainage engineering*, 121 (4), pp. 271–276.
7. Fuhrer J. (2003) Agro-ecosystem responses to combinations of elevated CO2, ozone and global climate change. *Agriculture, Ecosystems and Environment*, 97, pp. 1–20.

8. Jin C.X., Sands G.R., Kandel H.J. (2008) Influence of subsurface drainage on soil temperature in a cold climate. *Journal of irriganion and drainage engineering,* 134, pp. 83–88.
9. Kupčinskas V., Baniūnienė A., Žėkaitė V., Šidlauskas G. (2003) Mineralinių ir organinių trąšų bei meteorologinių sąlygų įtaka bulvių produktyvumui priesmėlio dirvoje (Mineral and organic fertilizers and meteorological conditions on the productivity of potato in sandy loam soil). *Žemdirbystė. LŽI ir LŽŪU mokslo darbai.* 84 (4), pp. 23–34. (in Lithuanian).
10. Lukianas A., Ruminaitė R. (2009) Periodiškai šlapių žemių sausinimo drenažu įtaka upių nuotėkiui (Periodic wet land drainage influence of river runoff). *Journal of Environmental Engineering and Landscape Management,* 17 (4), pp. 226–235. (in Lithuanian).
11. Maikštienė S., Šlepetienė A., Masilionytė L. (2007) Verstuvinio ir neverstuvinio pagrindinio žemės dirbimo poveikis glėjiškų rudžemių savybėms ir agrosistemų energetiniam efektyvimui (Mouldboard plunge and no mouldboard plunge main effect of tillage loamy soil properties and agro system energy effects). *Žemdirbystė,* 1, pp. 3–23. (in Lithuanian).
12. Meilutytė-Barauskienė D., Kovalenkovienė M., Irbinskas V. (2008) Lietuvos upių vandens ištekliai klimato kaitos fone (Lithuanian rivers of water resources in the background of climate change). *Geografija* 44 (2), pp. 1-8. (in Lithuanian).
13. Morkūnas V., Ramoška E. (2001) Drenažo nuotėkio reguliavimo tyrimai (Regulatory studies of drainage runoff). *Vandens ūkio inžinerija,* 16 (38), pp. 3–59. (in Lithuanian).
14. Ramoška E., Morkūnas V. (2006). Drenažo nuotėkio reguliavimo įtaka dirvožemio vandens režimui (Drainage runoff control on soil water regime). *Vandens ūkio inžinerija,* 30(50), pp. 5–14. (in Lithuanian).
15. Rimidis A. (2001) Drenažo veikimas limnoglacialiniuose dulkiškuose dirvožemiuose (Drainage performance glacial silty soils). *Žemės ūkio mokslai,* 2, pp. 48–53. (in Lithuanian).
16. Šidlauskas G., Švedas A. (2001) Agrometeorologinių veiksnių ir tręšimo azotu ryšys su vasarinių rapsų (Brassica napus) sėklų, žalių baltymų ir riebalų derliumi (Agro-meteorological factors, and relationship to nitrogen fertilization of spring rapeseed (Brassica napus) seeds, crude protein and fat yield). *Vagos,* 49(2), pp. 38–43. (in Lithuanian).
17. Wesstrom I., Messing I., Linner H., Lindstrom J. (2001) Controlled drainage – effects on drain outflon and water quality. *Agricultural Water Management,* 47, pp. 85–100.
18. Zhonghua J., Wan L., Shuxing F., Liang W., ShiYing T. (2006) Quantifying drainage components and salt and water balance in YinNan Irrigation District, China, based on a controlled drainage experiment. *Hydrol. Process,* 20, pp. 1875–1881.

PNEUMATIC PULSE METHOD IN THE TECHNOLOGY OF DEHYDRATION AND UTILIZATION OF THE SEWAGE SLUDGE

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Abstract
Sewage sludge is a specific bulky waste and its utilization is hampered by the presence of the environmentally dangerous contaminated substances in the composition presented mainly by heavy metals, pathogens and coagulants. At the same time sewage sludge may serve as a valuable biological raw material. Utilization of the sewage sludge is crucial environmental and economic challenge. Application of the pneumatic pulse method in the technology of dehydration and utilization of the sewage sludge may allow us to speed up the process of drying, reduce power consumption and capital investment, execute process of dehydration at lower temperatures and in less hazardous explosive conditions. Proposed solution is founded on the use of the compact equipment for dehydration and utilization, including pneumatic pulse drying method. For this purpose the pulser – an airflow feeder with required time intervals or pulses, was included in the technological process. In the process of the drying sewage sludge with the use of pneumatic pulse, there is no need to spend all the energy on evaporation of the water molecules and this fact significantly reduces power consumption. Preliminary calculations, taking into account laboratory data, showed that proposed technology of drying sewage sludge allows to reduce power consumption by 25% upon receipt of the dry sludge. The aim of the study is development of sewage sludge dehydration technology for further utilization of design solutions using the pulse method.
Key words: dehydration, pneumatic pulse method, sewage sludge, utilization of the sewage sludge.

Introduction

Operation of the urban sewage facilities in Latvia results in forming of approximately 23 thousand tons of sludge in dry matter annually (Gemste and Vucāns, 2010). Utilization of the urban sewage sludge (SS) is a demanding activity for any large city. This problem possibly is an issue not only for large cities but mainly for small towns and villages. SS is a specific bulky waste and its utilization is hampered by the presence of the environmentally dangerous contaminated substances in the composition presented mainly by heavy metals, pathogens and coagulants. At the same time SS may serve as a valuable biological raw material. Utilization of the SS is crucial environmental and economic challenge.

Strategy for the utilization of the SS in Latvia is defined by the main clauses of the Directive on waste 91/156/EEC of March 18 1991(Council Directive 91/156/EEC of 18 March 1991 amending Directive 75/442/EEC on wast, 1991):

- reduction of waste on the sites of its formation;
- reuse of the waste available or its processing;
- compost or energy recovery from waste;
- burning of waste;
- safe disposal of waste on the sanitary landfills (Gemste and Vucāns, 2010).

It is possible to distinguish the following main directions of the SS utilization:

- fertilization of the soil;
- burning;
- disposal.

The practice of burning SS is not accepted in Latvia.

Over the last years more than 50% of the produced SS every year remain on the temporary storage grounds near the treatment facilities or in other places (Gemste and Vucāns, 2010). It means that from year to year growing amount of the SS impedes proper work of the treatment facilities and may cause aggravation of the environmental situation.

High moisture content of the sludge is one of the main difficulties during the process of the SS utilization. The most common method of the sludge dehydration is drying of the SS on the so-called sludge sites where its moisture can be reduced up to 750-800 g kg^{-1}. However, drying requires vast land plots available. Moreover, moisture content of the sludge still remains too high. Recently we may notice increasing application of the mechanical methods to remove moisture from the SS allowing to reduce its percentage up to 800 g kg^{-1}. Using mechanical method of dehydration of the SS area required for the sludge sites can be reduced, however, power consumption increases.

Thermal drying of the SS is not applied in Latvia. Thermal drying of the SS is executed mainly with the aim to prepare the sludge for utilization and, as a rule, upon completion of the mechanical dehydration (Жуков et al., 1977). After the thermal dehydration SS is an untainted, free from worms and pathogens bulk material with 100-500 g kg^{-1} moisture content. Upon completion of the thermal drying, the SS can be considered as treated according to the conditions of the Cabinet Council No 362 of May 2, 2006 (Noteikumi par notekūdeņu dūņu un to komposta izmantošanu, monitoringu un kontroli, 2006). Owing to the fact that larger part of moisture is removed during the

process of the thermal dehydration overall amount of the sewage sludge decreases several times, thus facilitating its transportation and further utilization.

The task of the modern technology on treatment of the SS is to meet the contemporary challenge and transform SS into the product safe for the environment as well as application of the SS valuable components with the significant reduction of the sludge amount as a result of dehydration. Selection of the method applied shall be determined by the local conditions and taking into account physical and chemical properties of the sewage sludge, sanitary and epidemiological requirements, as well as technical and economic calculations.

The main disadvantages of the method of thermal dehydration of the SS which hampers its introduction into practice are as follows:

- relatively high power consumption;
- large capital investment and maintenance costs;
- some technologies of dehydration of the SS are potentially explosive.

Application of the pneumatic pulse method in the technology of dehydration and utilization of the SS may allow to speed up the process of drying, reduce power consumption and capital investment, execute process of dehydration at lower temperatures and in less hazardous explosive conditions.

The aim of the study is to develop sewage sludge dehydration technology for further utilization of design solutions using the pulse method. SS thermally dried with application of the pneumatic pulse dehydration method may be considered as:

- treated;
- having less weight due to moisture removal;
- less hygroscopic;
- environmentally safer;
- suitable for further recycling (soil fertilization, composting, burning).

Materials and Methods

Possibility for the application of the pneumatic pulse in the technology of dehydration and utilization of the SS is based on the major principles of the pneumatic pulse dehydration pilot unit for bulk materials patented in Latvia (Engeļbrehts et al., 2003). A proposed solution is developed due to the use of the compact equipment for dehydration and utilization, including pneumatic pulse drying method. For this purpose the pulser – an airflow feeder with required time intervals or pulses, was included in the technological process. The task of the pulser is to dislodge the water molecules from the dried material which then are taken away from the drying chamber.

Depending on the method of supplying heat, these drying units can be divided into conductive and convective ones. Equipment produced by the company VOMM which uses turbo technology can serve as an example of the most advanced technical solution for the thermal drying. This technology includes application of both conductive and convective mode of the heat exchanger supply. Since we failed to find any reference to similar equipment for drying SS with application of the pneumatic pulse technology, we applied equipment by VOMM as a prototype in conformity with the advertisement of VOMM.

The scheme of the pulser included in the technology of dehydration of the SS is shown in the Figure 1.

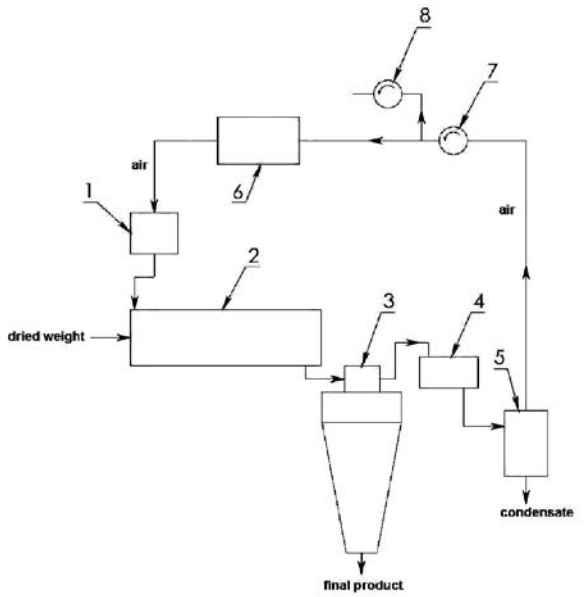

Figure 1. Scheme of the technological dehydration of the sewage sludge including pulser.
1 – pulser; 2 – drying chamber; 3 – cyclone; 4 - condenser; 5 – hydraulic cyclone; 6 – heat exchanger; 7 – blower; 8 – blower.

Table 1

General consumption data for the prototype and alternative (exemplified by use of natural gas as fuel)

Parameter	Unit	Value (prototype)	Value (alternative)
Heat consumption*	kJ L^{-1} H_2O	3015	2110
Boiler efficiency	%	86	86
Overall heat consumption*	kJ L^{-1} H_2O	nearly 3475	2455
Caloricity of fuel**	kJ m^3	34750	34750
Electric power*	kW L^{-1} H_2O	0.07	0.07
Guaranteed operation	Days $year^{-1}$	min. 342	min.342
Evaporating power	L h^{-1}	300-3500	390-4550
Humidity at the inlet	g kg^{-1}	700-850	700-850
Humidity at the output	g kg^{-1}	700-850	50-500

* Costs are calculated on the evaporation of 1 L of water

** l m^3 can evaporate approximately 10 L of water

Results and Discussion

Preliminary calculations, taking into account laboratory data, showed that proposed technology of drying SS allows to reduce power consumption by 25% upon receipt of the dry sludge. General consumption data for the prototype and alternative (exemplified by use of natural gas as fuel) are shown in the Table 1. in conformity with the advertisement of VOMM.

In the process of drying SS with the use of pneumatic pulse, there is no need to spend all energy on evaporation of the water molecules, and this fact significantly reduces power consumption. Application of the pneumatic pulse allows significantly reduce drying temperature. The optimal parameters of the pulser (magnitude and velocity of the air flow, number of pulses etc.) shall be selected taking into account properties and the scope of the sludge.

Taking into account particularity of the dried material and the fact that there is no similar equipment available, we need to determine general principal parameters of the equipment applied in technology of dehydration and utilization of the SS with the use of pneumatic pulse.

Conclusions

Calculations showed that application of the pneumatic pulse method in technology of dehydration of the SS allows to reduce power consumption by 25% upon receipt of the dried sludge. The process of drying can be executed at lower temperatures.

This technology of dehydration for utilization of the SS allows the following:

- decrease the area of land required for the sludge sites;
- reduce power consumption;
- significantly reduce the explosion hazard.

SS thermally dried with application of the pneumatic pulse dehydration method can be considered as

- treated;
- having less weight due to moisture removal;
- less hygroscopic;
- environmentally safer;
- suitable for further recycling (soil fertilization, composting, burning).

References

1. Council Directive 91/156/EEC of 18 March 1991 amending Directive 75/442/EEC on waste (1991) Official Journal of the European Communities, No 78, 26.03.1991, pp. 32–37. Available at: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=..., 21 March 2012 (in Latvia).
2. Gemste I., Vucāns A. (2010) *Notekūdeņu dūņas*. (Sewage sludge) Otrais papildinātais izdevums. Latvijas Lauksaimniecības universitāte, Jelgava, 276 lpp. (in Latvian).
3. Engeļbrehts A., Dobrodušins M., Gerdt O., Pētersons R. (2003) Paņēmiens birstošu materiālu žāvēšanai pseidoverdošā slānī, hidrotriecienu viļņu ģeneratora žāvētava tā realizēšanai. (The method of loose material drying in fludised bed, fluid shock wave generator and the dryer for the method realisation) Available at:

http://worldwide.espacenet.com/publicationDetails/biblio?DB=EPODOC&II=0&ND=..., 21 March 2012 (in Latvian).

4. 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, 21 March 2012 (in Latvian).
5. Жуков А.И., Мангайт И.Л., Родзиллер И.Д. (1977) *Методы очистки производственных сточных вод.* (Methods of treatment of the industrial wastewater) Стройиздат, Москва., 208 с. (in Russian).

BASIC FACTORS OF PARLIAMENT ELECTION RESULTS IN THE RURAL AREAS OF LATVIA

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Abstract
This work focuses on the demands of scientific and sociopolitical understanding of situation of Latvia where the interaction between different languages and cultures have produced the political map of today. The aim of this work was to determine the differences of election results between rural areas and the city area, as well as to determine the main factors affecting election results in rural areas. Results of the study show that the ethnic factor has a major role in interpretation of the distribution of election results. If the proportion of non-Latvians increased by one percent, then the proportion of voters for Harmony Centre would increase by 0.64 percentage points in Vidzeme and by 0.75 percentage points in Latgale.
Conclusions of the study: election results in rural areas differ significantly from the results in towns and cities, but the difference between rural areas and small cities is smaller compared to the cities under state jurisdiction; in rural areas, the national composition of the population has the greatest influence on the election results.
Key words: political parties, parliament elections, ethnic minorities.

Introduction

The 2011 and 2012 brought major political developments in Latvia. A referendum on the dissolution of parliament and a language referendum have not been fully assessed yet. This work focuses on the demands of scientific and sociopolitical understanding of situation in Latvia where the interaction between different languages and cultures have produced the political map of today.

Electoral geography studies in the world have widely examined the influence of various geographical factors on election results and the scope of this influence. By determining these correlations in various regions, it is possible to see how they correspond to the results of Latvian parliamentary elections. However, it must be noted that factors valid in some parts of countries may be completely insignificant in others.

In Latvia, the analysis of election results is a part of political science field. Most of the research done in this field is made by analyzing electoral programs of political parties or by conducting surveys which show the political preference of voters.

The aim of this work was to determine the differences of election results between rural areas and the city area, as well as to determine the main factors affecting election results in rural areas. The following objectives were defined in order to meet the aim of the paper to achieve the goal, parliamentary election results in the electoral districts of Latgale and Vidzeme were examined.

Since most of the research which looks at the distribution of parliamentary election results is done at the electoral district level, it doesn't take into account the full spatial variation that can be seen when election results are analysed at the local (parish) scale which has been done in this research.

Materials and Methods

The study analyses 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. For parties having overcome the 5% threshold, the statistics of the pluses and strikes of each candidate in all electoral districts were also examined.

When examining the effect of the ethnic factor on the results of political parties, they were summarized and analyzed at a municipal level (counties and cities under state jurisdiction). The mathematical analysis of the spatial dispersion of the results of political parties and the pluses and strikes of candidates, in turn, was conducted on a parish level. The obtained results thereby have a higher level of detail, and it is possible to compare the results of the 8th and 9th Saeima Election with the 10th and 11th Saeima (an administrative-territorial reform was carried out in the period between these elections).

The Central Election Commission does not publish election results on a parish scale, so the results of parishes were derived from the results of individual polling stations, by adding together the results of stations in one parish or town. In cases where there was no polling station in a rural area or parish adjacent to the town (e.g., Dobele parish), the town's result was also attributed to these territories.

Data on the national composition was obtained from the available information of the Office of Citizenship and Migration Affairs (PMLP) (Number of inhabitants in municipalities..., 2010). In addition, when examining the largest ethnic minorities in Latvia, it was necessary to determine the proportion of citizens within these groups, to what extent various

national minorities have integrated in the political environment of Latvia (Distribution of the inhabitants of Latvia..., 2010; Dribins, 2007). Unfortunately, after the administrative-territorial reform, the Office of Citizenship and Migration Affairs no longer publishes information about rural parishes, just releases information on the distribution of nationalities by municipality.

The work uses both quantitative and qualitative research methods. All initial data were tested for correspondence to normal distribution, using the Kolmagorov-Smirnov test. Considering that, in accordance with the Kolmogorov–Smirnov test, the zero hypothesis in relation to voting results in parishes and stations can be rejected; the t-test standard procedure was used for comparing averages. Analysis of the results of political parties, as well as of the results of individual candidates, in relation to the ethnic composition of the municipality or district was conducted by using linear regression analysis. A correlation coefficient was used as the indicator of the level of correlation. Following the standard used by Frolova (2005), the zero hypotheses – namely, that the resultant indication is not influenced by the factorial indication of the regression – was tested for regression models, checking whether zero was included in the credibility interval of the regression coefficient. If zero appeared in the credibility interval of the respective coefficients of the regression variables in the regression equation, the factor in question was excluded from the equation. All calculations have been done by the author in Microsoft Excel, with the exception of the Kolmogorov–Smirnov test, for which the program SPSS was used (Arhipova and Bāliņa, 2003).

Results and Discussion

Differences between rural and urban voters

Differences between rural and urban voters have been examined individually in the electoral districts of Vidzeme and Latgale. The need to examine these differences specifically in individual electoral districts is caused by the fact that parties submit different lists of candidates for each electoral district, and, since the 10th Saeima Election, each candidate may run in only one district. The differences in the lists of candidates between electoral districts already partially explain the spatial dispersion of election results.

The table (Table 1) shows that the overall number of voters in the period between the 8th and 11th Saeima Elections (2002–2011) has not significantly changed, dropping by less than five thousand or 1.7% compared

Table 1

Distribution of voters in the Vidzeme electoral district by type of territory

	8th Saeima	9th Saeima	10th Saeima	11th Saeima
Total number of voters in Vidzeme	265,240	246,403	264,863	260,506
Rural voters	123,465	113,574	124,104	122,917
Proportion (%) of rural voters	46.5%	46.1%	46.9%	47.2%
Town voters	104,295	97,048	103,515	100,782
Proportion (%) of town voters	39.3%	39.4%	39.1%	38.7%
City voters	37,480	35,781	37,244	36,807
Proportion (%) of city voters	14.1%	14.5%	14.1%	14.1%

Data: Central Election Commission of Latvia.

Table 2

Distribution of voters in the Latgale electoral district by type of territory

	8th Saeima	9th Saeima	10th Saeima	11th Saeima
Total number of voters in Latgale	156,835	132,524	128,155	115,486
Rural voters	65,688	52,681	48,238	42,543
Proportion (%) of rural voters	41.9%	39.8%	37.6%	36.8%
Town voters	33,588	29280	29107	27,010
Proportion (%) of town voters	21.4%	22.1%	22.7%	23.4%
City voters	57,559	50,563	50,810	45,933
Proportion (%) of city voters	36.7%	38.2%	39.6%	39.8%

Data: Central Election Commission of Latvia.

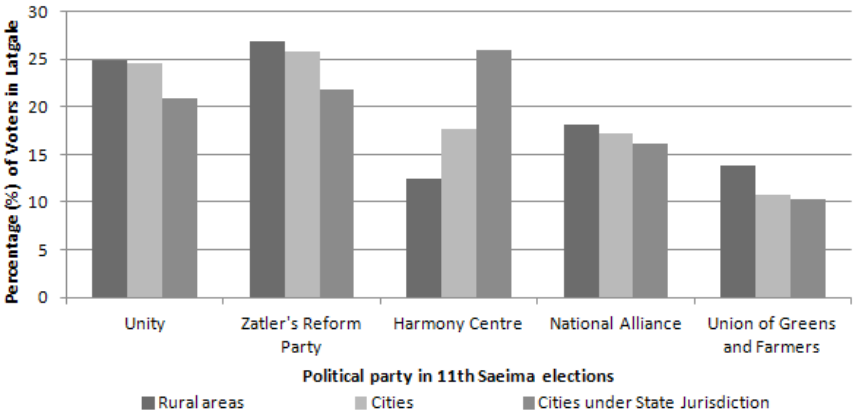

Figure 1. The results of political parties having obtained seats in the 11th Saeima in rural areas, towns and cities of the Vidzeme electoral district.
Data: Central Election Commission of Latvia.

to 2002. The number of voters in Vidzeme is relatively unchanged as this electoral district includes territories of the former Riga District in which the number of inhabitants, along with the number of voters, has increased during this time – examples include the municipalities of Mārupe and Garkalne. In the rest of the Vidzeme electoral district, the number of voters has generally decreased. Due to the significant increase of voters in the Pieriga area, the overall number of rural voters in the Vidzeme electoral district has also slightly increased, growing from 46.5% to 47.1%.

The situation in the Latgale electoral district, compared to Vidzeme, is different (Table 2). The overall number of voters in parliamentary elections in the period from 2002 to 2011 has gradually decreased, having dropped by 26.3% in 2011 compared to 2002. The number of rural parish voters in Latgale has decreased the most, falling by 35.2% in the examined period. The significant decrease in the number of rural voters in the Latgale electoral district has also caused a considerable decline in the role of rural voters, with their proportion falling from 41.9% to 36.8%. Thereby, the numerically-greatest part of voters is now formed by the two cities of the region (Daugavpils, Rēzekne), rather than by rural areas.

The results of the Vidzeme electoral district for the political forces that won seats in the 11th Saeima show substantial differences between rural and urban areas in terms of election results (Figure 1). Overall, the best result in the rural areas and towns of Vidzeme was achieved by Zatlers' Reform Party, while the strongest result in cities was shown by Harmony Centre.

The ethnic factor has a major role in interpretation of the distribution of election results in Vidzeme (Figure 3), as the proportion of non-Latvians is the lowest in the rural areas of Vidzeme, and greatest – in Vidzeme's cities (Jūrmala, Valmiera), which explains why Harmony Centre achieved its weakest result in rural areas (12.5%) and its best result in cities (26.0%). This trend is reverse for all other parties that had seats in the Saeima. It is also notable that the result of the Union of Greens and Farmers is much better in rural

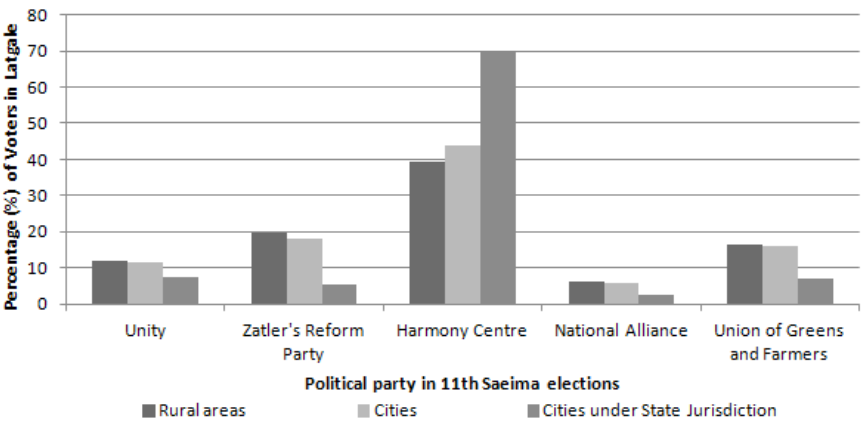

Figure 2. The results of political parties having obtained seats in the 11th Saeima in rural areas, towns and cities of the Latgale electoral district.
Data: Central Election Commission of Latvia.

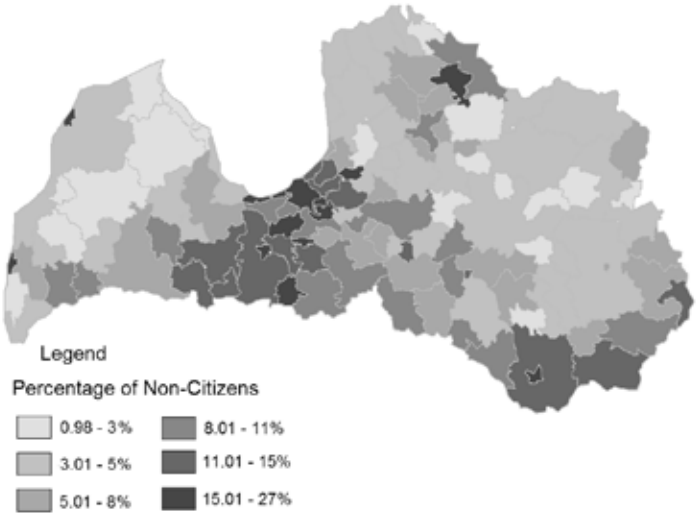

Figure 3. Proportion of non-citizens in counties and cities under state jurisdiction in 2010.
Data: Office of Citizen and Migration affairs of Latvia.

areas than in towns (by nearly 30%) while the rural area results of Unity, National Alliance and Zatlers' Reform Party are only slightly better than in towns. It suggests that the electorate of the Union of Greens and Farmers in the Vidzeme electoral district is mainly composed of people living in rural areas.

The results of the Latgale electoral district for the political forces that had seats in the 11th Saeima (Figure 2) show that Harmony Centre has achieved the highest result in rural areas, towns and cities alike, significantly overtaking the other political forces. Overall, the result of Harmony Centre is highest in cities and lowest in rural areas, with the situation being reverse for the other parties, the same as in the Vidzeme electoral district. In the case of Latgale this is also determined by the ethnic factor, considering that Latgale has the highest proportion of citizens of non-Latvian nationality, compared with other electoral districts. A significant difference is the fact that, compared with Vidzeme, the result of the Union of Farmers and Greens in rural areas compared to towns is not as high, which is explained by the fact that this party achieved a very high result in the town of Līvāni.

National composition of the population influence to the election results

When territorial dispersion of ethnic composition is analyzed, it is important to look at the proportion of non-citizens in a territory (Figure 3.). The analyzed electoral districts of Latgale and Vidzeme show the highest proportion of non-citizens in Latgale border counties (Daugavpils, Krāslavas, Dagdas county) and

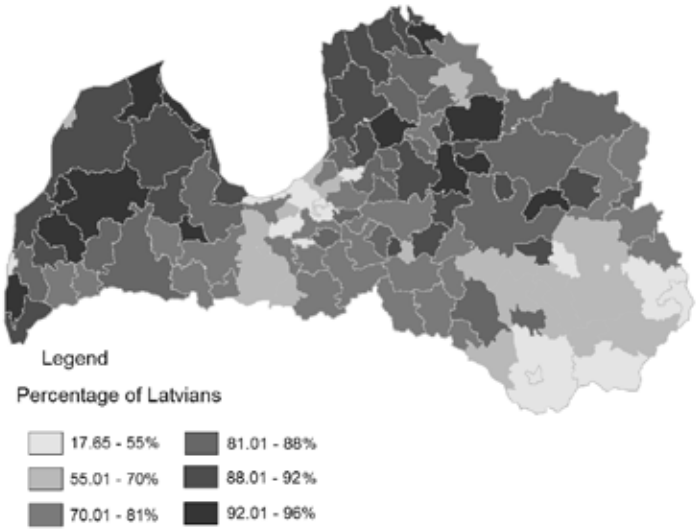

Figure 4. Proportion of Latvians in counties and cities under state jurisdiction in 2010.
Data: Office of Citizen and Migration affairs of Latvia.

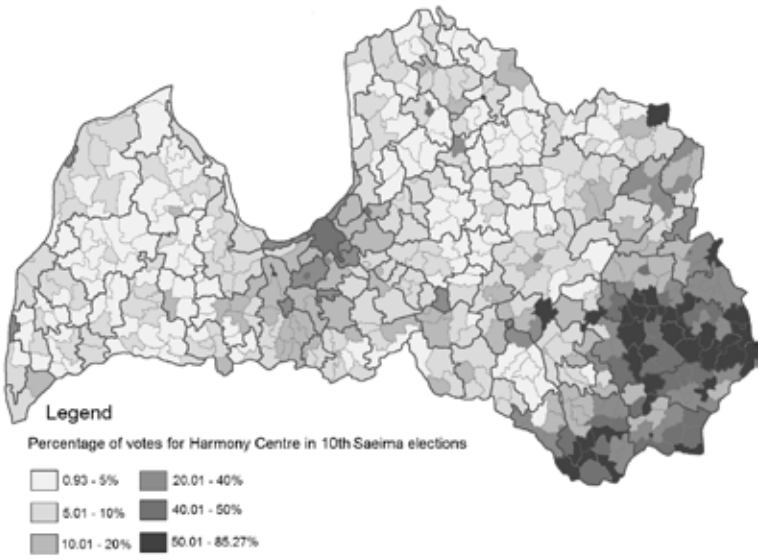

Figure 5. 10th Saeima election results for Harmony Centre in parishes and cities.
Data: Central Election Commission of Latvia.

Daugavpils. In Vidzeme the highest proportion of non-citizens is in Strencu county and in most of counties in the former Riga district (Salaspils and Olaines county has the highest proportion of non-citizens in Latvia with more than 25 % value). If electoral districts of Latgale and Vidzeme are comapared, it could be seen that even though the overall percentage of non-Latvians is higher in Latgale, proportion of the being non-citizens is much lower than in Vidzeme. Since cities under state jurisdiction have a higher non-citizen proportion in non-Latvian population, they have not been included in regression analysis for Vidzeme (Jūrmala and Valmiera) and Latgale (Daugavpils and Rēzekne) parameters.

In examined Vidzeme and Latgale electoral districts the proportion of Latvians differs quite significantly (Figure 4.). Overall Vidzeme has a higher percentage of Latvians in counties than Latgale. In Vidzeme 75% of all population are Latvians compared to 44% in Latgale, but proportion of Latvians has a high variation between counties in both electoral districts. In Vidzeme, those counties that are near Riga have much smaller percentage of Latvians than the rest of Vidzeme, while in Latgale the smallest percentage of Latvians is in cities under state jurisdiction and counties next to Russian and Belorussian borders.

Statistical information for election results can be easily shown in a more detailed level of parishes and cities (Figure 5). In many Latgale parishes Harmony Centre obtained more than 50% of all votes. In Vidzeme they had a high result in municipalities close to Riga, and only in Seda city and Pededzes parish they had more than 50% of all votes.

The regression analysis of election results in Vidzeme for those political parties who got into 10th Saeima show that combined election results (percentage from total votes) for Unity, Union of Greens and Farmers, National Alliance and For Good Latvia have a statistically significant positive correlation with the proportion of Latvians in a county. This correlation in Vidzeme counties explains more than 92% of all dispersion (R^2=92%).

Looking at proportion of non Latvians (%) in territorial units except cities under state jurisdiction, as the variable indication, and the proportion of votes (%) for Harmony Centre, as the resultant indication in Vidzeme, 49 observations were made. The determinative coefficient was 0.921. In turn, the regression coefficient was 0.643. The upper and lower limits of the regression coefficient were 0.588 and 0.699, respectively, which indicates that the zero hypothesis can be rejected, as the regression coefficient differs from zero with a very high probability. If the proportion of non-Latvians increased by one percent, then the proportion of voters for Harmony Centre would increase by 0.64 percentage points. The correlation between election results for Harmony Centre and proportion of non-Latvians in a county is almost as equally strong as the correlation between Latvian percentage in a county and combined election results for Unity, Union of Greens and Farmers, National Alliance and For Good Latvia, also explaining 92% of all dispersion.

If we compare the same parameters in Latgale, the tendencies are similar to Vidzeme; the only difference being that correlation between them is weaker mainly

because the number of observations is lower (19 in Latgale, 49 in Vidzeme), but still they are statistically significant.

Looking at proportion of non Latvians (%) in territorial units except cities under state jurisdiction, as the variable indication, and the proportion of votes (%) for Harmony Centre, as the resultant indication in Latgale, 19 observations were made. The determinative coefficient was 0.748. In turn, the regression coefficient was 0.863. The upper and lower limits of the regression coefficient were 0.607 and 1,119, respectively, which indicates that the zero hypothesis can be rejected, as the regression coefficient differs from zero with a very high probability. If the proportion of non-Latvians increased by one percent, then the proportion of voters for Harmony Centre would increase by 0.75 percentage points.

Discussion

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 pensioners 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.

Electoral geography studies examine the effect of geography on the results of political parties. Electoral geography also plays a role in the spatial correlations of the results of elected candidates. It is, in fact, the main factor determining the representation of African Americans in elected institutions in the United States of America. In the southern states, African Americans have a wider representation in the State Senate and other local elected institutions, but have a very low number of seats in the U.S. Congress; the situation is reverse in the northern states (Groffman and Handley, 1989).

By examining the differences in the results of US presidential elections in the period between 1988 and 2008, it has been concluded that there has been a gradual decrease in the number of states with similar results (within 3%) between Democratic and Republican candidates. In addition, a state's geographical location plays a major role in the state's political choices, with significant differences remaining between the "Democratic" western states and "Republican" southern states (Hopkins, 2009).

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).

Scientific studies usually look at how different social or ecomic factors influence parliamentary election results. In Latvia, the voter's attitude towards main political parties is not influenced by inflation rate before the elections which is a different situation than in Estonia. Unemployment rate and changes in workers monthly salary have a larger impact on election results in both Estonia and Latvia (Vikmane and Kreituse, 2009).

Even though ethnic factor is very relevant in parliamentary elections in Latvia, political alignment in "left" or "right" still plays a considerable role on the election results. That means that most of voters choose their political parties based on how close they are to their political alignment (Vikmane and Kreituse, 2010).

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 a publication of the author (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

1. The number of voters between 8th and 11th Saeima elections has decreased rapidly in Latgale electoral district with the greatest decrease in rural areas.

In Vidzeme, the number of voters hasn't changed significantly due to the high population increase in counties near Riga.

2. Election results in rural areas differ significantly from the results in towns and cities but the difference between rural areas and small cities is smaller compared to the cities under state jurisdiction.
3. In rural areas, the national composition of the population has the greatest influence on the election results. It can be admitted with a sufficient degree of plausibility that if the proportion of non-Latvians increased by one percent, the proportion of voters for Harmony Centre would increase by 0.64-0.75 percentage points.
4. Vidzeme election results for main political parties have a reverse situation in difference between rural and urban voters. The main reason for that is due to the different ethnic composition of voters which has the greatest influence on the results.

References

1. 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).
2. Agnew J. (1996) Mapping politics: how context counts in electoral geography. *Political Geography*, 15 (2), pp. 129–146.
3. Alexseev M. (2006) Ballot-Box Vigilantism. Ethnic Population Shifts and Xenophobic Voting in Post-Soviet Russia. *Political Behavior*. 28 (3), pp. 211–240.
4. Arhipova I., Bāliņa S. (2003) *Statistika ekonomikā. Risinājumi ar SPSS un Microsoft Excel.* (Statistics for Economics.Solutions for SPSS and Microsoft Excel). Datorzinību centrs, Rīga, 352. lpp. (in Latvian).
5. Frolova L. (2005) Korporatīvā sektora attīstība Latvijā un to ietekmējošie faktori. (The Development of the Corporate Sector in Latvia and Factors Influencing it). 690. (sēj.). *Latvijas Universitātes Raksti. Vadības zinātne*, Latvijas Universitātes akadēmiskais apgāds, Rīga, 52–67. lpp. (in Latvian).
6. 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.
7. Hopkins D. (2009) The 2008 Election and the Political Geography of the New Democratic Majority. *Polity*, 41 (3), pp. 368–387.
8. Iedzīvotāju skaits pašvaldībās pēc nacionālā sastāva (2010) Pilsonības un Migrācijas Lietu Pārvalde. (Population in municipalities by the ethnic composition. Office of Citizen and Migration affairs). Available at: http://www.pmlp.gov.lv/lv/statistika/Ird_arhivs.html, 20 September 2010 (in Latvian).
9. 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.
10. 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).
11. Latvijas iedzīvotāju sadalījums pēc nacionālā sastāva un valstiskās piederības (2010) Pilsonības un Migrācijas Lietu Pārvalde. (Latvian population by ethnic composition and nationality. Office of Citizen and Migration affairs). Available at: http://www.pmlp.gov.lv/lv/statistika/Ird_arhivs.html, 20 September 2010 (in Latvian).
12. McLaughlin E. (2009) Racial, Ethnic or Rational Voters. Splitting Tickets in South Africa. *Politikon*. 35 (1), pp. 23–41.
13. 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.
14. 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).
15. How Democratic is Latvia: Audit of Democracy (2005) Stratēģiskās analīzes komisija LU Akadēmiskais apgāds, Rīga, 309 p.
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. Vikmane E., Kreituse I. (2009) The Impact of the Socio-Economic Factors on the Electoral Behaviour in Young EU Member States: Problem-Posing and Methodological Approach. The Case of Latvia and Estonia. *European Integration Studies*, (3), pp. 230–236.
18. Vikmane E., Kreituse I. (2010) Consistent Choice at he Ballot Box: Perceptions That Matter in Latvia and Estonia. *European Integration Studies*, (4), pp. 78–84.

MOTIVATION TOOLS FOR EMPLOYEES IN REGIONAL MUNICIPAL ADMINISTRATIONS OF LITHUANIA

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Abstract
This article analyses the advantages of applicable measures of motivation, taking into consideration the internal environment of an organization as a whole and focuses on the impact of internal environmental factors upon the results of the organization. The paper is based on the survey results obtained by inquiring, municipal administration employees in Lithuanian districts in February-June 2010. The goal of the research was to propose and justify theoretical components for the motivation model of municipal administration employees. The major integrated groups of motivation measures that are the most influential to the factors of internal environment as the main results of research were identified. The authors focus on the positional adjustment of the combinations of motivation measures, in order to improve the motivation of municipal administration employees.
Key words: motivation measures, internal environmental factors, model.

Introduction

An important factor of an organization is its interaction and relationship with the environment. It has been pointed out that the success of any organization depends on the control of its environment. This is determined by the relationship of factors and variability of each factor that an organization should react. Organizations that aim for effective performance in the competitive environment should be aware of the environmental factors, determining their activity. The internal analysis of environment is important to know and assess the situation steadily in the public sector, in which the organization operates. The executives of organizations must expeditiously react to all changes in the internal environment and choose the best motivation measures for the employees (i.e. specific programs of employees' reaction) that allow implementation of activity guides provided in advance.

The organizations that aim for objectives and more effective results have to motivate their employees. Purposeful application of motivation measures might have a significant impact on the internal factors of organization environment. Main idea of the article was to present research which will help to find effective tools and methods for the motivation of employees in municipal administrations.

The object of the research: motivation measures that are the most influential to internal environmental factors of municipal administration employees in Joniškis, Pakruojis, Akmenė and Rokiškis districts in Lithuania.

The goal of the research is to propose and justify theoretical components for the motivation model of municipal administration employees.

In order to achieve this goal: 1) the specific motivation measures and internal factors of the environment have been investigated and the difficulties, when analyzing motivation, of a methodological nature have been examined; 2) the composition of internal environmental factors and combinations of motivation measures havebeen described; 3) the common connections of these measures have been determined and the positional adjustment of the combinations of motivation measures has been performed.

Materials and Methods

The internal environment is also important for the organization. Depending on the compatibility of factors, the organization shows an ability to work as one undivided unit and is able to achieve its compatibility and the compatibility of its single members (employees), i.e. the most important factor for the successful and effective results of the organization is to satisfy the needs of organization and employees, when striving for the organization goal (Denhard, 2001).

The analysis of scientific literature has been carried out (Diskienė and Marčinskas, 2007; Genevičiūtė-Janonienė and Endriulaitienė, 2008; Marcinkevičiūtė, 2010) the classifications of internal environmental factors and motivation measures in the public sector have been identified, the integrated table of internal environmental factors and motivation measures has been completed. During the investigation logical analysis, deduction, modeling and other methods suitable for the social studies were used.

The survey has been carried out in order to determine motivation measures that influence internal environment factors most and to identify the level of satisfying motivation measures in municipalities. The survey, inquiring municipal administration employees in Joniškis, Pakruojis, Akmenė and Rokiškis districts took place in February-June 2010. There were 220 respondents. This is about 83 percents of all employees

of municipal administration in these regions. Having analyzed the data, the major groups of motivation measures that are the most influential to internal environmental factors have been identified.

The article provides the systematised results of the survey (score average of the integral group of each motivation measure, using Likert scale (1-5-points)) that identifies the importance of a separate internal environmental factor for municipal administration employees. This kind of evaluation method was used and described by Clary, Snyder (1991) and developed by Rees (2008) and Donelson (2009) Sheal (2004) wrote about systematic view in the research.

Every factor of internal environment *in the group of material motivation measures* scored more than 4 points and was satisfied approximately by 3 points.

Results and Discussion

The analysis of internal environmental factors and groups of motivation measures

Organizations that strive to achieve satisfactory results have to evaluate the advantages and disadvantages of the environment. It is necessary to know different motivation measures that influence internal environment of the organization, i.e. internal factors (goals, tasks, technologies, personnel,

Table 1

The groups of internal environmental factors and motivation measures*

Internal environmental factors	Groups of motivation measures		
	Material-monetary	**Material-non-monetary**	**Psychological**
Organizational goals	Structure of wages, annual bonus for reasoned proposals, bonus for the achievement of the goal	Traineeship, seminars, refresher courses, service car, higher qualification	Evaluation of work, improvement of qualification, satisfaction with work, possibilities of self-expression, delegation of powers, group and individual decision making
Organization tasks	Congruity of wages and task content, annual bonus for reasoned proposals, bonus for implementation of the task	Traineeship, seminars, refresher courses, conferences, service car	The content of the task, improvement of qualification, autonomy of the activity, evaluation of the task on time, setting specialised tasks, decision making in groups, individual decision making
Technology of an organization	Extra pay for the qualification, annual bonus for a better use of time at work	Update of advanced technology on time	Working conditions, guarantee for occupation, making sure the quality of workplace, providing with better conditions to serve clients at work as well as outside the workplace
Employees of an organization	Extra pay for the qualification, extra pay for the work experience, extra pay (bonus) according to position held, annual bonus	Promotion that corresponds to the salary, promotion to the position with more responsibility, valuable presents as a reward, leisure events funded by organization	Honorable mention orally and in written, cancellation of disciplinary punishment, trust and responsibility, analysis of complaints
Organization structures	Annual bonuses	Collective leisure events funded by organization	Freedom of making decisions, rational style of management, information on organization development, compatibility of profession abilities and activity, feedback between employees and employers, feedback between employees and interested parties
Culture and climate	Sufficient wages, correspondence between wages and accomplished works	Comfortable conditions of workplace, sufficient amount of work resources	Cultivation of creativity, team formation, spread of information, identification of culture type, quality-oriented, certain customs, propagation of traditions and other cultural elements, striving for the innovation-friendly climate in the department

*Prepared on the basis of the research Lenkauskaite, Marcinkevičiūtė (2010).

structure, culture and climate). Some factors of internal environment are essential; others might be named as complementary. Nowadays, the flexibility of organizations' activity, their ability to adapt to constantly changing organization environment and needs of employees are the focus of attention. Because of the internal environmental changes of the organization (i.e. decreased wages, new duties, formation of competencies, etc.), there is a danger of losing the best employees in the public sector. The formation of motivation system and influence of internal environmental factors to work results is a relevant topic. Not all executives pay enough attention to such factors and the motivation function in their organizations is not systematic. They simply forget that motivation is extremely important as an effect and a factor to persons' activity that determines activity results, influences emotions and causes certain behavior and efficiency.

The difference between motivated and unmotivated employees lies not only behind the inequality of circumstances in objective reality but also on the different interpretations of the same reality. For this reason, *motivation of employees* is usually related to the totality of objectives that an employee orients towards one's duty. Each of these objectives has a coefficient of probability, which allows imagining these objectives in one's work and functions.

Such motivation measures as extra pay for better use of time or awareness and applicability of technologies (2.8 points) did not satisfy municipal administration employees. It should be noted that according to the Republic of Lithuania Law on Public Service (2009) such bonuses or extra pays are not mentioned. However, they may be provided according to the internal order of municipality regulations (Public administration law, 2010).

Application of *non-material motivation measures* (seminars, traineeship, trainings, courses) for municipal administration employees is sufficient (the importance for the employees is evaluated by 4 points; satisfactory - 3.4 points). As the most significant factors of internal environment that are lacking skills were work with people (3.9 points) and tasks related to information (4 points) (there are not enough skills to perform these tasks, which require using various technologies and performing tasks that require direct interaction with the interest groups). The analysis of municipality plans and reports confirmed the results of the survey because there are training and refresher courses organized in municipalities. In comparison with 2007, the amount of finances increased in 2008 (for the refresher courses and traineeship in 2007 - LTL 229.4, in 2008 - LTL270.2)

Implementing the education plan for civil servants, there are certain trainings organized on the following topics: introductory teaching for new employees, management skills (for executives), strategy and policy, questions related to the European Union, interaction and communication, public administration issues, foreign language skills, computer literacy, etc.

According to municipal administration employees, the group of *psychological motivation measures* is the least satisfactory group of motivation measures (2.8 points on the average) identified. Municipal administration employees are dissatisfied with the style of management, information about organization activity, feedback, climate (the importance of measures is 4.2 points). As demotivating factors of internal environment, the regulated structure of an institution (4.2 points. satisfactory level 2.9 points) and classification groups of the personnel (importance - 3.8 points, sufficiency - 2.9 points) have been mentioned. The lack of psychological motivation measures is influenced by too many regulated procedures. Municipality administration employees are liable to department managers and administration director. Regulated relationship between the lower and higher positions of servants and communication with them as with "equal" also influences dissatisfaction of municipal administration employees in such psychological climate.

Scientific literature (Palidauskaitė, 2007; Šilingienė and Vandenabeele, 2004; Locke, 2004) suggests that trust and striving for innovations dominate in public sector; however, the results of the survey have shown that such motivation measures are insufficient because employees are dissatisfied with the quality of information, the quality should be taken into account, few possibilities for creativity. Lithuanians authors: Zuperkiene, Zilinskas (2008) and Urboniene (2009) wrote about motivation factors and methods; though their findings and proposals were oriented not toward municipal sector.

According to the data of the survey, municipal administration employees are dissatisfied with the motivation measures applied, the applicability level of these measures is insufficient, motivation of employees is not systematic. For the different factors of environment, different influence is made on the different groups of motivation measures. Such situation shows that positional compatibility of internal environmental factors and motivation measures is a complicated process. That is why it is important to ensure their connections.

Motivation model of municipal administration employees

As Denhardt (2001) notices, in a new paradigm of management, a model, in an abstract way, denotes the connections of social phenomenon, i.e. connections between the elements of the system.

The stages of system creation model for motivation show what an organization has to do in order to increase the productivity of employees and achievement of the organization goals. Appliance of motivation measures may positively affect the behavior of employees if these measures are timely and purposeful. In the scientific literature, motivation is not a constant state, it needs to be updated, changing the measures of motivation. The motivation of employees is a changing process which depends on the needs of an employee, his/her character features, and economic condition of the state. When the environment is changing, the motives of employees are also changing (Public administration law, 2010).

Having analyzed the components of motivation measures and combinations of internal environmental factors, their common connections have been determined and positional adjustment of motivation measures combinations has been done.

Referring to the scientific analysis and practical data of surveys, the motivation model of municipal administration employees has been prepared. The components of motivation model are presented in Table 2.

First model component. *Problem analysis of internal environmental factors and employees' motivation in municipalities.* First of all, internal environmental factors should be identified, regarding the classifications suggested in scientific literature. Examples that were analyzed at work might be selected as factors (organization goals, objectives, technology, personnel, structure, and culture). Then the possibilities of municipalities to adapt to the internal environment are determined. Application of motivation measures in municipalities is regulated by the municipal legal framework, although the internal order of municipality regulations outline certain variety of applicable measures mentioned above. According to the classification groups, certain classifications of internal environmental factors applied in municipal administrations should be determined, which would be used to create a motivation model.

Next step would be to substantiate theoretical and practical motivation of employees. Having analyzed annual reports, annual reports of employees' assessment, municipal administration directors' reports, and having questioned municipal administration employees (interview, discussions in groups, individual conversations, etc.), the problems of employees' motivation are identified. The final step would be to determine classification groups of motivation measures that would be applied, motivating employees.

Second model component. *Selection of direct or indirect measurement methods of employees'*

Table 2

Components for motivation model of municipal administration employees**

Components of the model	Purpose of the components
1) Problem analysis of internal environmental factors and employees' motivation in municipalities	To identify the factors, determining adaptation of the employees to internal environment of organizations; to determine possibilities of municipalities to adapt to internal environment. To determine classification groups of internal environmental factors. To substantiate theoretical and practical motivation of employees To identify motivation problems of employees. To determine classification groups of motivation measures.
2) Selection of direct or indirect measurement methods of employees' motivation	To determine the significance of direct and indirect measurement methods of employees' motivation (in a particular situation). According to the results of analysis and assessment, select the most appropriate methods that would provide accurate information.
3) Preparation and strategic decision making in municipalities (regarding the survey of employees' motivation)	To determine the action plan of employees' motivation survey To form the combination of internal environmental factors and criteria of motivation measures To make sure rational distribution and use of municipal resources, in order to implement the survey of employees' motivation. To predict measures for stimulation of new strategic survey innovations.
4) Implementation monitoring of survey action plan of municipal employees' motivation	To observe motivation changes of municipal employees, to follow their results To observe changes of internal environmental factors in municipalities To analyze reasons of changes in employees' motivation and internal environmental factors.

**Adopted on the basis of Lenkauskaite (2010).

motivation. The significance of direct and indirect measurement methods of employees' motivation (in a particular situation) is determined. Direct motivation measurement methods might be as follows: scales of rank assessment, descriptive indexes of work, scales of faces, methods of critical events, and interview. The following indicators such as the amount of absenteeism, the numbers and duration of being late, the turnover of employees, and the number of intended resignations might be used for indirect measurement methods. According to the results of chosen analysis and assessment, the most appropriate methods that would provide accurate data are selected. It is advisable to use Likert's scale (5 points system), when employees can evaluate the significance of motivation measures and the level of satisfaction by these measures in the analyzed organizations.

Third model component. *Preparation and strategic decision making in municipalities (regarding the survey of employees' motivation).* In the action plan of employees' motivation survey, the sequence of actions should be clearly defined. Integrated table of the combination of internal environmental factors and criteria of motivation measures might be prepared, which would classify motivation measures for each internal environmental factor. During the employees' motivation survey, consistent distribution and use of municipal resources should be secured. There should be a certain part of assets provided in the budget for the survey. Having implemented the action plan and having done the exhaustive analysis and assessment of survey results, measures for the stimulation of new strategic initiatives should be provided.

Fourth model component. *Implementation monitoring of survey action plan of municipal employees' motivation.* When applying recommendations formed by survey data, it is necessary to observe motivation changes of municipal employees, follow results of the activity that are significant for the motivation system. Since the environment and a person's state are constantly changing, employees' needs should be newly assessed (approximately once a year, if it is possible–once per six months). It is advisable to observe the changes of internal environmental factors in municipalities, following them and adapting according to particular situations. The causes for changes of employees' motivation and internal environmental factors should be analyzed, predicting the alteration of internal environmental factors and motivation measures. The feedback (if it is necessary) would help to modify the model of motivation.

In summary, it should be pointed out that in order to motivate employees it is necessary to know what might motivate each person in a particular situation. A particular situation not necessarily satisfies everyone's needs. It should be emphasized that several different, sometimes even contradictory factors, (that might be formed as a response to different environmental factors or different pressure of social systems) motivate peoples' behavior.

Conclusions

1. The activity of public sector organizations is formalized because the rules and regulations involve almost all its members' behavior. In organizations, all roles are clearly and exactly formulated, people's behavior provided, independent of personal and sometimes professional features.
2. Work in the public sector is not diverse and sometimes it reminds of a routine because it is necessary to work in accordance with legal acts, administrative procedures, rules and other regulations. In private sector, on the contrary, employees receive freedom when doing tasks and the tasks themselves are more innovative, they constantly change and vary.
3. As the studies showed employees are dissatisfied with too many "bureaucratic – formal" procedures (freedom for decision making has been evaluated 3 points), information about the organization activity, and feedback (the importance of measures is 4.2 points, and satisfaction level is 2.9 points). Decision making freedom is influenced by regulation of decision making and that is why too much time is wasted for signatures and permissions, instead of solving the problem directly.
4. Employees of municipal administrations are dissatisfied with motivation measures applied, the level of measures applicability is insufficient and there is no system in employees' motivation. Different internal environmental factors are differently influenced by different groups of motivation measures.
5. In order to motivate employees, it is necessary to know what can motivate each person in a particular situation. A particular situation not necessarily satisfies everyone's needs. Sometimes even contradictory factors that might be formed as a response to different environmental factors or different pressure of social systems motivate peoples' behavior.
6. Analysis of internal environment is important for knowing and assessing present situation in public sector, where organizations function. Executives of organization must expeditiously react to changes in internal environment and select the best motivation measures for employees (i.e. special reaction programs for employees) that allow implementation of activity guides provided in advance.

References

1. Clary E., Snyder M. (1991) A Functional Analysis of Altruism and Prosocial Behavior. Review of Personality and Social Psychology. London: Open University Press, pp. 10–14.
2. Denhardt R.B. (2001) *Viešųjų organizacijų teorijos*. (Theories of Public Organizations). Vilnius, pp. 12–18. (in Lithuanian).
3. Donelson A. (2009) *Intrinsic Motivation*. London: Kogan Page, pp. 4–6.
4. Diskienė D., Marčinskas A. (2007) *Lietuvos vadybinis potencialas. Būklė ir perspektyvos.* (Lithuania managerial potential. Status and Perspectives). Vilnius, pp. 38–45. (in Lithuanian).
5. Genevičiūtė-Janonienė G., Endriulaitienė A. (2008) Darbuotojų asmenybės savybių ir darbo motyvacijos sąsajos. *(Personal qualities of employees and motivation to work interface). Psichologija*, Nr. 38, pp. 100–114. (in Lithuanian).
6. Lenkauskaite A. (2010) Organizacijos vidinės aplinkos įtaka Joniškio rajono savivaldybės administracijos darbuotojų motyvavimui. (Influence of internal environment of organization for staff motivation in Joniškis district municipal administration). *Magistro tezės.* Vad. Marcinkevičiūtė. Kaunas, pp. 23–28. (in Lithuanian).
7. Lietuvos Respublikos Valstybės tarnybos įstatymo pakeitimo įstatymas. (Republic of Lithuania Law of Public Service). (2009) *Valstybės žinios*, Nr. 75-3065, pp. 16–22. (in Lithuanian).
8. Lietuvos Respublikos Vietos savivaldos įstatymas. (Republic of Lithuania Law on Local Self-Government). (2010) *Valstybės žinios*, Nr. I-533. pp. 8–12. (in Lithuanian).
9. Locke E. (2004) Psichological needs and the facilitation of integrative process. *Journal of Pesonality*, No. 63, pp. 397–427.
10. Marcinkevičiūtė L. (2005) Savivaldybės darbuotojų motyvavimo teoriniai ir praktiniai aspektai. (Theoretical and practical aspects of employees' motivation in municipalities). *Ekonomika ir vadyba: aktualijos ir perspektyvos*, Nr. 5, pp. 239–247. (in Lithuanian).
11. Marcinkevičiūtė L. (2005) Teoriniai ir praktiniai darbuotojų motyvavimo modeliai. (Theoretical and practical models of employees' motivation). *Organizacijų vadyba: sisteminiai tyrimai*, Nr. 34 (39), pp. 77–92. (in Lithuanian).
12. Marcinkevičiūtė L. (2010) *Darbuotojų motyvavimo modeliai: teoriniai ir praktiniai aspektai.* (Employees' motivation models: theoretical and practical aspects). Kaunas, pp. 45–54. (in Lithuanian).
13. Palidauskaitė J. (2007) Motyvacijos unikalumas valstybės tarnyboje. (The uniqueness of motivation in public service). *Viešoji politika ir administravimas*, Nr. 19, pp. 33–45. (in Lithuanian).
14. Public administration law (2010) Lietuvos Respublikos Viešojo administravimo įstatymo pakeitimo įstatymas. (Republic of Lithuania Law of Public administration). *Valstybės žinios*, 2006, Nr. X-736. pp. 22–31. (in Lithuanian).
15. Rees C.J. (2008) Organisational Change and Development: Perspectives on Theory and Practice. *Journal of Business Economics and Management*, 9 (2), pp. 87–89.
16. Šilingienė V. (2004) Įmonių motyvavimo sistemų kūrimas ir vertinimas. (Development and evaluation of business motivation systems). *Organizacijų vadyba: sisteminiai tyrimas*, Nr. 31 (39), pp. 60–61. (in Lithuanian).
17. Sheal L. (2004) Systems Organization: The Management of Complexity. Milton Keynes: Open University Press, pp. 12–14.
18. Urboniene A. (2009) Factors Motivating Young Women for the Professional Career in the Field of Technological and Physical Sciences. Transformations in Business & Economics, 8 (3), pp. 164–174.
19. Vandenabeele W., Depre R., Hondeghem A., Shufeng Y. (2004) The motivational patterns of civil servants. *Viešoji politika ir administravimas*, Nr. 13 (21), pp. 53–55.
20. Žaptorius J. (2007) Darbuotojų motyvavimo sistemos kūrimas ir jos teorinė analizė. (Development of motivation system for employees and its theoretical analysis). *Filosofija. Sociologija*, T. 18, Nr. 4, pp. 105–117. (in Lithuanian).
21. Zuperkiene E., Zilinskas V. (2008) Analysis of Factors Motivating the Managers Career. Inzinerine Ekonomika-Engineering Economics (2), pp. 85–91.

RISKS IN AGRICULTURE AND THEIR ASSESSMENT METHODS

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Abstract
Agriculture is a unique sector, because it is associated with negative outcomes stemming from imperfectly predictable biological and climatic variables. These variables include natural adversities (for example, pests and diseases), climatic factors are not within the control of agricultural producers. So in agriculture it is very important to identify and evaluate risk, only then decisions made in farm will bring profit and other positive results. Scientific literature distinguishes a lot of methods for risk evaluation, but it is not clear what methods could be adapted in agriculture sector. This article presents main risk types in agriculture and their features as well as introduces most popular risk evaluation methods and their possible use in assessing risks in agriculture.
Key words: agriculture risk, risk evaluation methods.

Introduction

Market-ground organized business involves risks as a consequence of various factors. Rapidly changing market conditions increase competition and intensify the need to evaluate and manage risk. If the risk is not evaluated, it can lead to loss or even bankruptcy.

Agricultural business organizations are facing risks more than other business sectors, because agricultural products and services are related to natural processes and biological assets: plant's and animal's diseases. Agriculture is particularly exposed to adverse natural disasters, such as insect damage and poor weather conditions that negatively impact production. The economic costs of major climatic disasters may increase further in the future due to climate changes. Agriculture is a unique sector mainly because of these reasons: seasonality; agricultural products are more prone to damage; climate fluctuations; agricultural demand, supply and price fluctuations. Thus, in agriculture it is very important to evaluate and manage agriculture risk, only then it will be possible to make effective and timely decisions.

The purpose of this article is to identify main types of agriculture risks and to analyze their evaluation methods.

Tasks:

1. To analyze scientific literature and identify risk concept.
2. To exclude main risk types in agriculture and circumstances of their occurrence.
3. To analyze risk evaluation methods and their features.

Materials and Methods

In order to analyze the risk assessment methods, first of all it is important to understand what the risk is and how it is defined. For this purpose scientific and academic literature (Aleknevičienė, 2005; Jaeger et al., 2001; Simaitienė, 2005; Rutkauskas, 2001; Vaughan, 1997; Buškevičiūtė et al., 1999; Laskienė, 2004; Rainey, 2002; Clark et al., 1996; Cindyniques et al., 2008) was analyzed, and using generalization method a risk definition was formulated.

After determining risk and its concept, risk performances in agriculture sector were analyzed. Therefore, agriculture economics literature (Hardarker et al., 2004; Patrick, 1992; Dickson, 1996; Johnson, 2007; Adams, 2008; Barnett et al., 2009; Dao et al., 2004; Simaitienė, 2007) was investigated, and using generalization, synthesis techniques five types of agriculture risk were extricated.

Finally, theoretical analysis of risk evaluation methods (Rasche, 2001; Laskienė, 2003; Ahmed et al., 2007; Bandyopadhyay et al., 1999; Bagliano et al., 1998; Dimitrakopoulos et al., 2010) by using deduction, comparison, generalization techniques used for agricultural risk assessment, identifying their features and their specific use were selected.

Results and Discussion

Defining risk concept

Market-ground organized business inevitably involves risks as a consequence of various factors. When environment is constantly changing, business is characterized by uncertainty, insecurity and risky decisions. Rapidly changing market conditions and increased competition result in intensifying the need to assess and manage risk. Underrated risk can influence decision-making efficiency.

Risk management is relevant to entrepreneurs seeking to succeed and survive in a dynamic market. Risk management is not possible without a risk assessment because risk assessment can only determine whether risk level is acceptable or not, whether the benefits of the use of human and financial resources will help to achieve expected result. Risk assessment is a complex process, but it is necessary to carry out a profitable business activity.

In order to determine the risk significance for decision making process, it is important to identify

Table 1

Risk concept (made by author)

Concept	Researches
The risk is perceived not only as an opportunity to lose, but also as an opportunity to win	Jaeger et al. (2001); Simaitienė (2005); Rutkauskas (2001)
Risks perceived as possibility of unwelcome event	Vaughan (1997); Buškevičiūtė et al. (1999); Laskienė (2004)
The risk is perceived as likely to suffer a loss	Rainey (2002); Clark et al. (1996); Cindyniques et al.(2008)

the risk. According to Rockett (1999), the concept of risk is broad enough and is often confused with concepts such as harm, danger, threat or uncertainty. According to other opinion, the risk is an event or its outcome probability. Risk includes both the possible benefits, as well as loss. Jasanoff (1998) considers that the concept of risk analysis is the most important step in decision-making process that can help to carry out profitable activities.

The scientific literature presets different approaches to risk. Table 1 illustrates three most popular risk concepts.

Meanwhile, Aleknevičienė (2005) argues that persons usually take risk for the possibility of getting better results than expected. According to the author's work, in the market activity is developed in order to earn maximum profit and gain the greatest market share, so it is clear that the main goal is to win. Meanwhile, the likelihood of defeat is desired to be eliminated completely or reduced to a minimum, so this paper will use the concept of risk as possibility to suffer financial losses.

Table 2

Risk types in agriculture and their features (compiled by the author)

Risk type	Features	Researches
Production	Risk occurs because agriculture is affected by many uncontrollable events that are often related to weather, including excessive or insufficient rainfall, extreme temperatures, hail, insects, and diseases. Technology plays a key role in production risk in farming. The rapid introduction of new crop varieties and production techniques often offers the potential for improved efficiency, but may at times yield poor results, particularly in the short term. In contrast, the threat of obsolescence exists with certain practices (for example, using machinery for which parts are no longer available), which creates another, and different, kind of risk.	Hardarker et al. (2004); Patrick (1992)
Financial	This type of risk depends on the way the firm's capital is obtained and financed. A farmer may be subject to fluctuations in interest rates on borrowed capital, or face cash flow difficulties if there are insufficient funds to repay creditors. The use of borrowed funds means that a share of the returns from the business must be allocated to meeting debt payments. Even when a farm is one hundred percent owner financed, the operator's capital is still exposed to the probability of losing equity or net worth.	Dickson (1996); Johnson (2007); Adams (2008); Barnett et al. (2009); Patrick (1992)
Personal	This type of risk may be caused by such events as death, divorce, injury, or the poor health of a principal in the firm. In addition, the changing objectives of individuals involved in the farming enterprise may have significant effects on the long run performance of the operation.	Dao et al (2004); Hardarker et al. (2004); Patrick (1992)
Political	This risk stems from changes in policies and regulations that affect agriculture. This type of risk generally arises from changes in policies affecting the disposal of animal manure, restrictions in conservation practices or land use, or changes in income tax policy or credit policy, subsidies granting.	Hardarker et al. (2004); Patrick (1992)
Economic	This type of risk is related to trade transactions and participants opportunities to meet its obligations under certain economic conditions in the country. This risk reflects the country's economic risk indicators.	Simaitienė (2007); Hardarker et al. (2004)

Risk types in Agriculture

Risk in agriculture as a concern has been around the world since 1933, when the base of risk analysis was established by Frank Knight (2002). By analysing literature in the field of agricultural risk (Halter, 1971; Dillon, 1971, Hardaker, 2006; Landanyi, 2003), we can find out that evaluating and managing risk in agriculture is difficult. The enterprise of agriculture is subjected to a lot of uncertainties. The reason for the difficulty is confusion and differences of opinion about what risk is and how it can be measured.

According to Gomez-Limon et al (2003) risk is present in all agricultural management decisions as a result of different sources of uncertainty, and as long as farmers have different preferences with respect to risk, the choices they make will be conditioned to a lower or higher degree by a risk-minimizing process. Moreover, the increasing role of uncertainty from climate change and globalization creates a greater need for tools to efficiently manage different sources of uncertainty (Ritchie et al., 2004; Stigter, 2008; Hansen et al., 2009).

Agricultural economics literature has provided several studies to estimate farmer risk preferences, but most of the studies include evaluation only of one kind of risk, e.g. political, economic or financial. In Table 2 the main risk type in agriculture and their circumstances of their occurrence are illustrated.

As it is seen in Table 2, agriculture risks have different sources, but they also are related to each other. After analyzing risk and their features, it is possible to identify interaction between them. Farmers decide what kind of crop to produce according to the situation in the market, price level, what kind of policies are in their country, the climate conditions, in what region their land is located, and, of course, in any kind of decision making process farmers personal opinion and expectations are very important. So it is clear that production risk is related to economic, political and personal risks. Economic risk depends on political situation in the country, and also depends on various regulations. Financial risk depends on legislation (that is a part of political risk) and on general economic situation in the country. Thus, analyzing risks in agriculture and seeking evaluation of them, it is difficult to separate different types of risk, because risks interact and influence each other.

Table 3

Risk methods for evaluating risks in agriculture (compiled by the author)

Method	Risk type				
	Personal	Production	Economic	Political	Financial
What if? - hazard analysis method, that determines what can go wrong and judging the likelihood and severity of those situations occurring.	✓	✓		✓	
Fuzzy matrix - it is mathematical algorithm to predict future performance			✓	✓	
Scenario Analysis - This method analyzes from “bad” to “good” variations of circumstances and compares them with the most probable situation or the base case.	✓	✓	✓	✓	✓
Event Tree Analysis- ETA - this is a logical model to determine how the unexpected event could take place	✓		✓	✓	✓
Fault Tree Analysis - FTA -it is the diagram showing the logical relationships between errors of the subsystems and components.	✓		✓	✓	✓
Delfi technique - this method is based on a variety of expert opinion. There is a special questionnaire and experts are interviewed.			✓	✓	
Monte-Carlo simulation - it is the method where computer simulations of future are developed and expected rate of return and risk indexes are obtained.			✓		✓
Cost-benefit analysis - CBA- this method weighs the potential costs and expected profitability, the method uses the time value of money.			✓	✓	✓
Risk-at-value -VAR- VAR method is a statistical method that measures potential losses, which over time with a certain probability business entity will face.				✓	✓
Variation-covariation method - this method uses massive historical data, usually it is very adaptive			✓	✓	✓

Methods for risk evaluation in agriculture

Risk evaluation in scientific literature contains many models of both quantitative and qualitative terms. According to Braendeland, Refsdal, Stolen (2010), qualitative risk modelling techniques are focused on the causes and consequences, while the quantitative - focused on events of probability calculations.

For agricultural risk assessment the same risk evaluation methods that are used by other sectors are used. As was mentioned before, agriculture is a specific sector, due to its close relation with nature. After analyzing scientific literature (Rasche, 2001; Laskienė, 2003; Ahmed et al., 2007; Bandyopadhyay et al., 1999; Bagliano et al., 1998; Dimitrakopoulos et al., 2010), main risk evaluation methods used for agriculture risk evaluation were denoted. Results of this analysis are shown in Table 3.

As it is seen in Table 3, agricultural economics literature has provided several studies to estimate farmer risk preferences, but most of the studies include evaluation only of one kind of risk, e.g. financial, personal, economics or political, so it is difficult to choose effective evaluation method, as quantitative methods usually require massive statistical data, special technique and knowledge, and it takes time to calculate the result. Meanwhile, qualitative methods deeply depend on knowledge and experience or a decision-maker. So advantages of quantitative methods are disadvantages of qualitative methods and vice versa.

In general, all these studies focus on a limited set of risk sources, and only few researchers such us Xiaoy Su, Zhonghua Zhao, Huijie Zhang, Zhiqiang Li, Yong Deng (2011) seek to evaluate a few or more risks at the same time with one evaluation model. They suggest using only one integrated risk assessment model for evaluating risks in agriculture. This model evaluate in integrated way not only different kind of risks, but also different kind of data (quantitative and qualitative).

In author's opinion one integrated risk evaluation model for agriculture risks evaluation would be very useful because of these reasons: risks in agriculture are related with each other, so using one integrated model will be possible to evaluate situation very briefly; while evaluating the risk, it is important to take into account not only statistical, quantitative data, but also circumstances – qualitative data; using one model instead of many decisions will be made on time, quickly and efficiently.

Conclusions

1. Market activity is developed in order to earn maximum profit and gain the greatest market share, so the main goal of any activity in market is profit. Meanwhile, the likelihood of defeat is desired to eliminate risk completely or reduce it to a minimum. So risk concept can be defined as possibility to suffer financial losses.
2. Main risk types in agriculture are: personal, production, economic, political, and financial. These agriculture risks have different sources, but they also are related to each other. After analyzing risk and their features, it is possible to identify interaction between them. Farmers decide what kind of crop to produce according to situation in the market, price level, what kind of policies are in their home country, climate conditions and in what region their land is situated, and, of course, in any kind of decision making process farmers personal opinion and expectations are very important. It is obvious that production risk is related to economic, political and personal risks. Economic risk depends on political situation in the country, and also depends on various regulations. Financial risk depends on legislation that is a part of political risk and on general economic situation in the country. So analyzing risks in agriculture and seeking to evaluate or manage them, it is difficult to separate different types of risk, because risks interact and influence each other.
3. Several quantitative and qualitative methods are used for risk evaluation: What if? Variation-covariation method, Risk-at-value, Cost-benefit analysis, Monte-Carlo simulation, Delfi technique, Fuzzy matrix, Scenario Analysis, Event Tree Analysis and Fault Tree Analysis. One and the same method can be used for few types of risks to be evaluated.
4. For risk evaluation in agriculture, it would be very useful to use integrated risk assessment model due to these reasons: risks in agriculture are related with each other, so using one integrated model will be possible to evaluate situation very briefly; while evaluating the risk, it is important to take into account not only statistical, quantitative data, but also circumstances – qualitative data; using one model instead of many decisions will be made on time, quickly and efficiently.

References

1. Adams K.F. (2008) Risk perception and Bayesian analysis of international contruction contract risks: The case of payment delays in a developing economy. *International Journal of Project Management*, 26, pp. 31–38.

2. Ahmed A., Kays B., Amornsawadwatana S. (2007) A review of techniques for risk management in projects. *An International Journal*, 1, pp. 22–36.
3. Aleknevičienė V. (2005) *Investicijų rizikos valdymo žemės ūkio sektoriaus įmonėse metodologiniai aspektai.* (Methodological aspects of investment risk management in enterprises of agricultural sector). habilitacijos procedūrai teikiamų mokslo darbų apžvalga: socialiniai mokslai, ekonomika (04 S). Lietuvos žemės ūkio universitetas. Akademija (Kauno r.). pp. 3–10. (in Lithuanian).
4. Braendeland G., Refsdal A., Stolen K. (2010) Modular analysis and modeling of risk scenarios with dependencies. *The Journal of Systems and Software*, 83, pp. 1995–2013.
5. Barnett B.J., Coble K.H. (2009) Are Our Agricultural Risk Management Tools Adequate for a New Era? *Choice*s, 24, pp. 36–39.
6. Bandyopadhyay K., Mykytyn Peter P., Mykytyn K. (1999) A framework for integrated risk management in information technology. *Management Decision*, 37/5. pp. 437–445.
7. Buškevičiūtė E., Mačeriskienė I. (1999) *Finansų analizė*. (Financial Analysis). Technologija, Kaunas. pp. 30–46. (in Lithuanian).
8. Cindyniques P., Antipolis S. (2008) Risk + barriers = safety? *Safety Science*, 46, pp. 221–229.
9. Clark E., Maroi B. (1996) *Managing Risk in International Business*. International Thompson Business Press, London, pp. 101–132.
10. Dimitrakopoulos D., Kavussanos G.M., Spyrou S.I. (2010) Value at Risk models for Volatile Emerging Markets Equity Portfolios. *The Quarterly Review of Economics and Finance*, 50, pp. 515–526.
11. Dao H., Peduzzi P. (2004) Global evaluation of human risk and vulnerability to natural hazards. *Enviroinfo*, 1, pp. 1–12.
12. Dickson G.W. (1996) An analysis of vendor selection systems and Decisions. *Journal of Purchasing*, 2, pp. 28–41.
13. Dillon J.L. (1971) An expository review of bernoullian decision theory is utility futility? *Review of Marketing and Agricultural Economics*, 39, pp. 380.
14. Gomez-Limon J., Arriaza M., Riesgo L. (2003) An MCDM analysis of agricultural risk aversion. *European Journal of Operational Research*, 15, pp. 569–585.
15. Hansen J., Mishra A., Rao K., Indeje M., Kinuthia R. (2009) Potential value of GCM-based seasonal rainfall forecasts for maize management in semi-arid Kenya. *Agricultural Systems*, 101, pp. 80–90.
16. Hardaker J.B. (2006) Some issues in dealing with risk in agriculture. *Working Paper Series in Agricultural and Resource Economics*. University of New England, NSW, Armidale, pp. 23–36.
17. Hardaker J.B., Huirne R.B.M., Anderson J.R., Lien G. (2004) *Coping with risk in agriculture*. -CABI Publishing, 2nd ed, pp. 1–22.
18. Halter A.N., Dean G.W. (1971) *Decisions under Uncertainty with Research Applications.* Cincinnati, South-Western Press, U.S., 266 p.
19. Jaeger C.C., Renn O., Rosa E.A., Webler T. (2001) *Risk, Uncertainty, and Rational Action.* Earthscan Publication, UK, pp. 13–19.
20. Johnson T.C. (2008) Volume, liquidity, and liquidity risk. *Journal of Finance Economics*, 87, pp. 388–417.
21. Jasanoff S.H. (1998) The Political Science of Risk Perception. *Reliability Engineering and System Safety*, 59, pp. 91–99.
22. Knight F.H. (2002) *Risk. Uncertainty and Profit*. Beabard books, Houghton Mifflin Publishers, Washington, pp. 1–6.
23. Laskienė D. (2004) *Verslo rizikos valdymo modelis.* (Business Risk Management Model). daktaro disertacija. Akademija, Kaunas. pp. 5–25. (in Lithuanian).
24. Patrick G.F. (1992*) Managing risk in Agriculture.* Cooperative Extention Service, Purdue University, West Lafayette, pp. 5–10.
25. Ritchie J., Yahaya S.G., Dutta Harris T., Bange M. (2004) Risk management strategies using seasonal climate forecasting in irrigated cotton production: a tale of stochastic dominance. *Australian Journal of Agricultural and Resources Economics*, 48, pp. 65–93.
26. Rainey R. (2002) *Risk Management: Overview of CORE Analysis*. University of Arkansas Cooperative Extension Service Printing Services. pp. 1–5.
27. Rasche T. (2001) *Risk Analysis Methods – a Brief Review*. The University of Queensland, Mineral Industry Safety and Health Center (MISHC), pp. 7–14.
28. Rutkauskas V. (2001) *Finansinės rizikos valdymas: daktaro disertacija*. (Financial risk management: the doctoral thesis). Technologija, Vilnius. pp. 10. (in Lithuanian).

29. Rockett J.P. (1999) Definitions are not what they seem. *Perpetuity Press*, 1, pp. 37–47.
30. Su X., Zhao Z., Zhang H., Li Z., Deng Y. (2011) An Integrative Assessment of Risk in Agriculture System, *Journal of Computational Information Systems*, 7, pp. 9–16.
31. Stigter K. (2008) Coping with climate risk in agricultural needs farmer oriented research and extension policies. *Scientia Agricola*, 65, pp. 108–115.
32. Simaitienė V. (2005) Tarptautinių atsiskaitymų rizikos valdymas: magistratūros studijų baigiamasis darbas. (Risk Management for International Settlements: masters thesis). LŽŪU, pp. 8–22. (in Lithuanian).
33. Vaughan E.J. (1997) *Risk Management*. John Willey and Sons, Chicago. pp. 149–205.

FINANCIAL DISTRESS DETERMINANTS: THE SURVEY OF LITHUANIAN FARMS

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Abstract
Farm financial distress can be determined by many factors. Farm failure can be the result of macroeconomic environment, unsuccessful farmer's management decisions, and even natural forces. Different financial distress determinants may have different influence on a farm financial position. This study presents average financial ratios (leverage, return on assets, and return on equity) and single ratio of rental equivalent to gross margin according to farm size, land quality, economic size, farmer's age and type of farming in Lithuania. The new approach to financial distress diagnosis requires classifying farms into financial positions. Considering average financial ratios and single ratio of rental equivalent to gross margin, farms were classified according to financial positions in order to estimate these methods' suitability for financial distress diagnoses. Using study results, farmers can identify their position according to the average ratios. This study could be a guide for farmers making the financial management decisions.
Key words: financial position, financial distress determinants, Melichar's procedure, Lithuanian farms.

Introduction

Financial distress determinants and financial distress prediction are highly important to farm business, as European farms are generally family businesses. Therefore, farm' s financial distress can result in farmers and their families losing their employment, homes and their way of life.

It is worth mentioning that much of the literature of financial distress determinants is not specific to agriculture. On the other hand, a number of researches have noted that industrial sector is a significant determinant in the financial distress prediction models. It is fairly certain, that farms financial distress determinants studies are not sufficient. In a number of cases, demand to analyze farm financial distress determinants increased after post-crisis periods. Some of the evidence shows, that researchers pay more attention to farm financial distress determinants or prediction after 1980's agricultural recession, 1990's massive collapse of the cooperatives in the United States and after 1998's Year of the Russian crisis. It is worth looking through farm financial ratios after 2008-2009 World's economic and finance crisis.

Economists Jolly et al., (1984) analysed incidence, intensity, and duration of financial distress among farms. Hughes, Richardson, Rister (1985) focusing problem was effects of sustained financial stress on the financial structure and performance of the farm sector. Wadsworth, Bravo-Ureta (1992) analysed financial performance of New England dairy farms. They used a multidimensional measure developed by Melichar's procedure (1985) and a logit regression model was estimated to examine the determinants of financial performance. Franks (1998) and Dietrich, Arcelus, Srinivasan (2005) have paid attention to predicting financial distress in farm businesses. The field that interested Vercammen (2007) was, was farm bankruptcy risk as a link between direct payments and agricultural investment. Cross, Buccola, Thomann (2009) focused on cooperative liquidation under competitive stress. Aleknevičienė, Aleknevičiūtė (2010) analysed financial ratios of farms in the European Union. The recent work by Aleknevičienė, Aleknevičiūtė, Martirosianienė (2011) addressed the issue of financial management and financial ratios in Lithuanian Farms.

The object of research – the financial distress determinants. The aim of the research – to set financial distress determinants and classify them according to financial position of Lithuanian farms according to the farm size, land quality, economic size, farmer's age and type of farming.

The main objectives: (1) to develop the methodology of financial distress determination; (2) to present the determinants of financial distress in Lithuanian farms; (3) to classify Lithuanian farms in financial positions according to financial distress determinants. The new approach to financial distress diagnosis requires classifying farms into financial positions. The focusing problem is which determinants could be useful to classify farms in financial positions.

Materials and Methods

Financial distress is a process, caused by the economic difficulties and (or) poor farm management. It starts when the farm cannot carry out its obligations. Therefore, the farm has to sell its assets, lay off employees, creditors no longer have the prospects of recovering investments or dealing with creditors can be made complicated. If obligations become disproportionate to the farm's assets, the loss could not be covered by assets. This is the reason why farm

can no longer exist in its present form. Financial distress begins in short-term insolvency and ends with leaving farm business.

Jolly et al. (1985) argue, that financial distress can be determined by examining long-run characteristics (profitability, liquidity, solvency and risk-bearing ability) of the farm business and measured indirectly by aggregate indicators (include land value trends, foreclosure and loan delinquent rates, or loan losses taken by creditors). However, Jolly et al. (1985), Wadsworth, Bravo-Ureta (1992) analysis of financial distress determinants has focused on the leverage (debt-to-asset (D/A)) ratio.

Melichar's' procedure, used in Wadsworth, Bravo-Ureta (1992) study to determine a farm's financial position, combines 3 financial ratios and equity level. Financial ratios needed to implement Melichar's scheme, were suggested D/A ratio, where D/A is total debt as a percentage of total farm assets; return on assets (ROA), equal to net farm income before interest payments minus the value of unpaid labour as a percentage of total farm assets; return on equity (ROE) equal to net farm income minus the value of unpaid labour and interest payments as a percentage of equity, and equity level (total farm assets minus debt) to classify farms into four financial positions: (1) good; (2) fair; (3) stressed; (4) vulnerable (Wadsworth and Bravo-Ureta, 1992).

According to Melichar's procedure (Figure 1), farms are classified in the good financial position if they are not experiencing financial distress. Farms are classified as fair if they are not able to sustain their equity or fully service debt in the long-term, but they are not in serious trouble in the short-term. Farms in vulnerable position are currently experiencing financial trouble and may not survive in the long-term, while farms classified in the distressed group have big solvency problems unless returns improve (Wadsworth and Bravo-Ureta, 1992). Farms with ROE from -5% to + 5% are financially stable in the short-term. In the long-term, farms will need to make some operating changes and may be vulnerable to

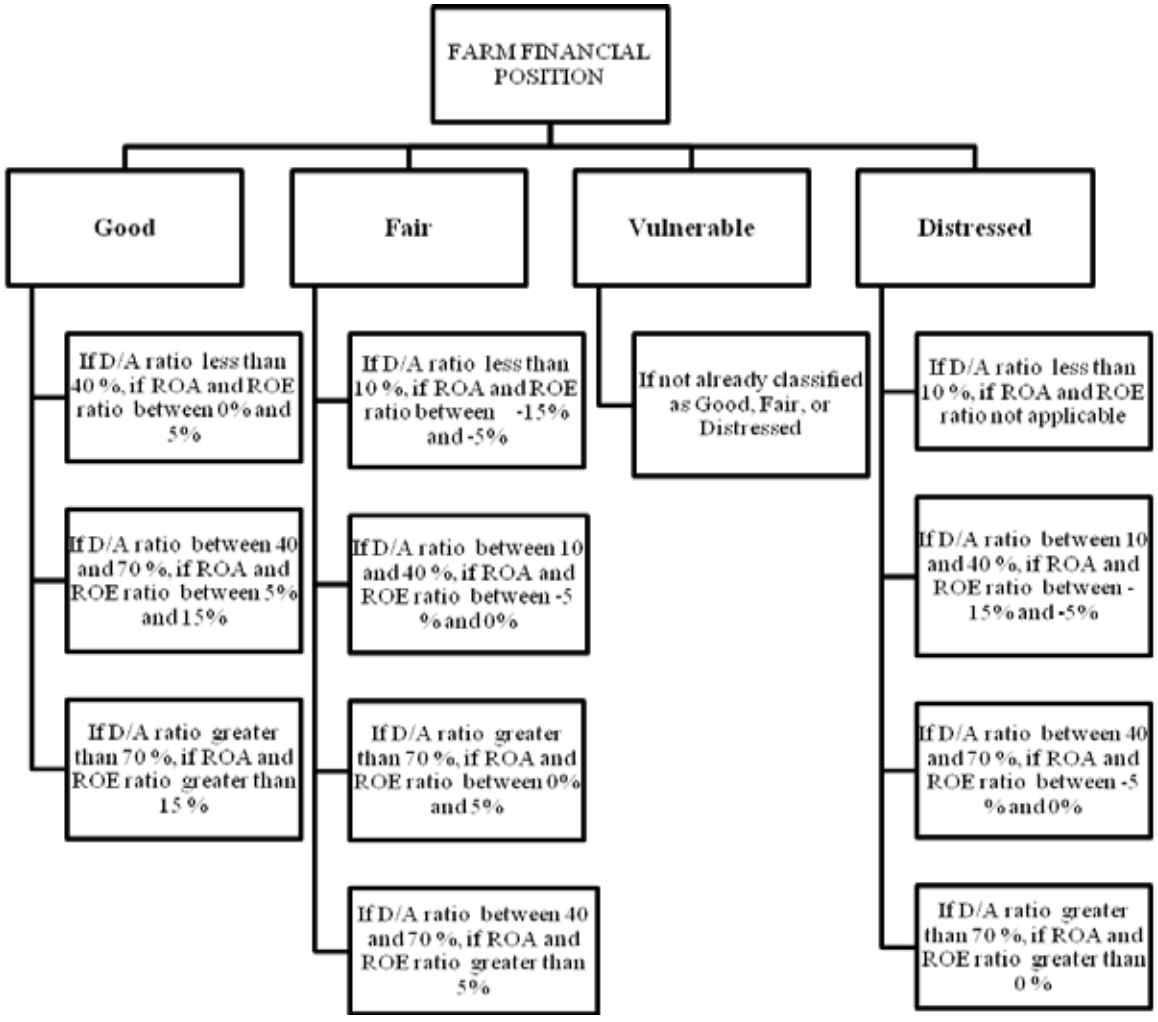

Figure 1. Farm Financial Position According to Melichar's Procedure, With Farm Equity Greater than 50000$ (made by authors according to Wadsworth, Bravo-Ureta, 1992).

Table 1

RE/GM Boundary Values Which Discriminate Farms between the Financial Distress Categories

Financial distress categories	Boundary values according to the authors		
	Poole (1986)	Harrison, Tranter (1989)	Franks (1998)
Stable	less than 15%	less than 25%	between 0 and 25%
Vulnerable	between 15 and 25%	between 25 and 50%	between 25 and 40%
Distressed	greater than 25%	greater than 50%	greater than 40%

Made by authors according to Franks, 1998; Poole, 1986; Harrison, Tranter, 1989.

assets value declines. Farms with ROE less than -5% are failing at modest to rapid rate (Jolly et al., 1985).

On the other hand, Franks (1998) focused on categorising farms into one of three financial distress categories and accompanied by a comprehensive range of specification tests. The researcher found out that the importance of increasing returns on equity as a strategy for reducing the likelihood of being classified as financially distressed. Franks (1998) gave some critics on Melichar's procedure. He systematized a number of arguments of scientists and argues that financial distress measures based on leverage more properly indicates the exposure to risk, but it conveys no information on the opportune interest repayments. Leverage does not reveal the income-generating potential of the farm and does not give information about the liquidity of the farmer's asset structure.

Franks (1998) focused on Crabtree (1985) and Temple, Turner (1995) suggested to simplify the selection of a basket of ratios. Researchers suggest using the single ratio of rental equivalent to gross output (RE/GO), where rental equivalent is the sum of interest and rent paid. The main argument was found out, that interest and rent are financial charges that cannot be displaced in time. Equally, failure to pay interest and rent commitment as they fall due may result in foreclosure of loans or loss of tenure. Poole (1986), Harrison, Tranter (1989) improved RE/GO measure by using rental equivalent to gross margin (RE/GM). Gross margin is calculated as the difference between the gross output and the variable costs of farm (Florey, et al., 2004). Deducting variable costs from gross output more accurately represents the cash generated by the farm business that is available to finance rent and interest payments (Franks, 1998). Both Poole (1986) and Harrison, Tranter (1989) identify three categories of financial distress, but disagree over the boundary values with which to discriminate between the categories (1 Table).

Whilst these authors agree that financial distress can be adequately represented by three categories, they clearly have not agreed regarding the appropriate boundary values. Furthermore, Franks (1998) argues, that Harrison, Tranter (1989) suggested upper limit of 50% may imply such severe financial distress that few practical alternative strategies remain open to the farmer.

The main data source for this article is a Farm Accountancy Data Network (FADN). The specific data used are based on Lithuanian family farm records from a total of 1300 operations for the calendar year 2010. Selected farms cover all districts, natural zones and reflect different farming conditions.

Results and Discussion

To determine Lithuanian farm's financial position, Melichar's procedure with operators with equity greater than 50 000 $ (or 130495 Lt according to 31 December 2010 the official exchange rate), as all analysed groups of Lithuanian farms had Equity greater than 130495 Lt were used. In the survey 3 financial ratios (D/A, ROA and ROE) and financial distress measure RE/GM. Tables 2–6 provide the financial positions of the 1300 Lithuanian farms in the sample were used.

Table 2 presents Lithuanian farm grouped according to farm size average financial ratios and average single ratio of RE/GM. According to Melichar's' procedure farming group with greater than 150 hectares size can be classified as good. Farming group between 50 and 100 hectares size can be classified as vulnerable. Other groups are classified as fair. It means, that 47.2% of Lithuanian farm grouped according to the farm size are in fair financial position, 30.6% are in good and 22.2% are in vulnerable financial position. D/A ratio between 1.4 and 16.2% shows that all farms, grouped according to the farm size, are not risk averse. Generally, the bigger is the farm size, the higher is the ROE ratio. According to ROE ratio, the biggest farms (from 50 to 100 hectares, 100 – 150 hectares and greater than 150 hectares) are financially stable in the short-term. In relation to this argument, the authors can conclude, that the farm size determines farm's financial position.

According to single ratio of RE/GM all farming groups according to the farm size can be classified as stable, because according to Poole (1986), Harrison, Tranter (1989) and Franks (1998) suggested boundary values RE/GM are less than 25%. In relation to this argument, authors can state, that rent and interest

payments do not determine Lithuanian farms according to the farm size financial position. It is very possible, that rent and interest payments are quite small compared to gross margin.

Table 3 presents financial ratios of Lithuanian farms grouped according to the land quality. The farm group with land quality greater than 45 points is classified to be in good financial position. It presents that about 37.7% of analysed farms are in good financial position. Other groups are classified as vulnerable, because they were not classified in any other position according to Melichar's procedure. D/A ratio between 6 and 11.3% shows that all farms, grouped according to the land quality, are not risk averse. Generally, high land quality determines farms financial position.

As shown in the Table 3, about 41% of analysed Lithuanian farm's are oriented towards less favoured areas and 59% towards normal areas. According to Melichar's procedure, farming group in less favoured areas are classified as fair. Farm in normal areas are classified as vulnerable. Farms located in less favoured areas have marginally higher D/A ratio comparing with farms located in normal areas.

According to single ratio of RE/GM all farming groups according to the land quality can be classified as stable, because boundary values of ratio RE/GM are less than 25%. It is almost certain, that rent and interest payments do not determine Lithuanian farms financial position.

Table 2

Average Ratios and Financial Positions of Lithuanian Farms According to Farm Size in 2010

Farm size, ha	Ratio			Re/ gm, %	Financial position		Number Of farms	Structure Of farms, %
	Stability, %	Profitability, %			According to stability & Profitability	According to re/gm		
	D/a	Roa	Roe					
10	1.4	-6.0	-6.1	1.5	Fair	Stable	59	4.5
10–< 20	2.2	-6.4	-6.5	1.7	Fair	Stable	117	9.0
20–< 30	4.1	-5.2	-5.5	3.2	Fair	Stable	71	5.5
30–< 40	3.7	-6.3	-6.6	4.5	Fair	Stable	68	5.2
40–< 50	7.1	-5.3	-5.9	4.0	Fair	Stable	118	9.1
50–< 100	9.2	-0.4	-0.5	4.4	Vulnerable	Stable	288	22.2
100–< 150	15.7	-1.2	-1.4	6.5	Fair	Stable	181	13.9
>= 150	16.2	2.2	2.8	7.0	Good	Stable	398	30.6
Total							1300	100

Made by the authors. Source: FADN.

Table 3

Average Ratios and Financial Positions of Lithuanian Farms According to Land Quality in 2010

Land quality, in points	Ratio			Re/ gm, %	Financial position		Number of farms	*Structure* of farms, %
	Stability, %	Profitability, %			According to stability & Profitability	According to re/gm		
	D/a	Roa	Roe					
< 32	11.3	-4.8	-5.3	2.2	Vulnerable	Stable	93	7.2
32–< 35	6.0	-5.0	-5.4	2.9	Vulnerable	Stable	121	9.3
35–< 45	9.0	-3.9	-4.4	4.7	Vulnerable	Stable	596	45.8
>= 45	9.3	1.7	1.9	5.6	Good	Stable	490	37.7
Total							1300	100
Less favoured areas	10.4	-3.1	-3.5	3.6	Fair	Stable	533	41.0
Normal areas	8.0	-2.1	-2.3	5.6	Vulnerable	Stable	767	59.0
Total							1300	100

Made by the authors. Source: FADN.

Table 4

Average Ratios and Financial Positions of Lithuanian Farms According Farmer's Age in 2010

Farmer's age	Ratio			Re/gm, %	Financial position		Number of farms	Structure of farms, %
	Stability, %	Profitability, %			According to stability & Profitability	According to re/gm		
	D/a	Roa	Roe					
< 40	10.4	-3.2	-3.8	8.1	Fair	Stable	439	33.8
40–49	10.0	-1.3	-1.5	11.0	Fair	Stable	439	33.8
>= 50	6.5	-2.3	-2.5	5.5	Vulnerable	Stable	422	32.5
Total							1300	100

Made by authors. Source: FADN.

Table 5

Average Ratios and Financial Positions of Lithuanian Farms According Types of farming in 2010

Types of farming	Ratio			Re/gm, %	Financial position		Number of farms	Structure of farms, %
	Stability, %	Profitability, %			According to stability & Profitability	According to re/gm		
	D/a	Roa	Roe					
Organic farms	6.78	-7.9	-8.4	5.3	Fair	Stable	103	7.9
							-	-
Specialised in cereals, oilseeds and protein crops	12.6	-1.9	-2.3	8.5	Fair	Stable	402	30.9
General field cropping, mixed cropping	7.0	2.4	2.7	5.1	Good	Stable	157	12.1
Horticulture and permanent crops	10.0	9.8	11.1	0.8	Vulnerable	Stable	51	3.9
Specialised in dairying	8.4	-1.4	-1.5	2.6	Vulnerable	Stable	327	25.2
Grazing livestock	3.9	-6.9	-7.2	2.9	Fair	Stable	92	7.1
Specialised in granivorous	11.9	0.4	0.4	0.9	Good	Stable	20	1.5
Field crops – grazing livestock, combined	8.0	-4.8	-5.3	5.2	Vulnerable	Stable	198	15.2
Various crops and livestock, combined	6.3	-5.2	-5.8	1.6	Fair	Stable	53	4.1
Total							1300	100

Made by the authors. Source: FADN.

As it can be seen from Table 4, Lithuanian farms are grouped according to farmer's age: less than 40 years and between 40 and 49 years old farmers are classified to be in a fair financial position, but those who are over 50 years old, are classified as vulnerable. There is no difference in financial ratios if you compare the group of farmers who are younger than 40 years with farmers who are between 40 and 49 year age group. On the other hand, farms with the owner who is over 50 have almost 4 percentage points smaller D/A ratio. Therefore, it is quite possible that younger farmers are more risk averse than older ones. It seems that all farms, grouped according to farmer's age, ROE ratio are greater than -5%; therefore, these farms are financially stable in the short-term. In relation to this argument, authors can state, that farmer's age have influence on farms financial position. According to single ratio of RE/GM all farming groups according to farmer's age can be classified as stable, because boundary values of ratio RE/GM are less than 25%.

Table 5 presents Lithuanian farm financial ratios according to types of farming.

As it can be seen from Table 5, about 7.9% of analysed Lithuanian farms are organic. According to Melichar's procedure, organic farms can be classified in fair financial position. It is very probable that organic farm will fail, because ROE ratio is less than -5%. According to single ratio of RE/GM, organic

Table 6

Average Ratios and Financial Positions of Lithuanian Farms According to Economic Size in 2010

Economic size (esu)	Ratio			Re/ gm, %	Financial position		Number of farms	Structure of farms, %
	Stability, %	Profitability, %			According to stability & Profitability	According to re/gm		
	D/a	Roa	Roe					
4–< 8	2.4	-8.5	-8.9	2.7	Fair	Stable	123	9.5
8–< 15	4.2	-6.3	-6.6	3.6	Fair	Stable	195	15.0
15–< 25	8.4	-3.7	-4.1	4.5	Vulnerable	Stable	156	12.0
25–< 50	8.6	0.8	0.9	4.5	Good	Stable	234	18.0
50–< 100	16.4	2.1	2.6	5.4	Good	Stable	284	21.8
100–< 250	17.2	4.7	6.1	6.2	Vulnerable	Stable	232	17.8
>=250	16.0	2.8	3.8	7.3	Good	Stable	76	5.8
total							1300	100.0

Made by the authors. Source: FADN.

farms can be classified as stable, because RE/GM ratio is 5.3%.

According to financial ratios (Table 5) in a good financial position are general field cropping, mixed cropping farms and specialised granivorous farms. It is very small part of Lithuanian farms, because general field cropping, mixed cropping and specialised granivorous farms present accordingly 12.1% and 1.5% of all Lithuanian farms. Specialised cereals, oilseeds and protein crops, grazing livestock, various crops and livestock, combined farms are in a fair financial position. The structure of these farms with all analyzed farms is accordingly 30.9%, 7.1% and 4.1%. Horticulture and permanent crops, specialised dairying and field crops – grazing livestock, combined are classified to be in vulnerable financial position, because they were not classified in any other position according to Melichar's procedure. These farms together with all analysed farms constitute 44.3%.

D/A ratio between 3.9% and 12.6% shows that all farms, grouped according to the types of farming, are not risk averse. According to ROE ratio most of farms (specialised cereals, oilseeds and protein crops, general field cropping, specialised dairying, specialised granivorous) are financially stable in the short-term. It is very probable that grazing livestock, field crops – grazing livestock, various crops and livestock, combined farms will fail, because ROE ratio is less than -5%. In relation to this argument, authors can state, that type of farming determines farm financial position.

According to single ratio of RE/GM, all farming groups can be classified as stable, because boundary values of ratio RE/GM are less than 25%. It is very possible, that rent and interest payments are quite small comparing with gross margin.

Table 6 presents financial ratios according to economic size.

Farms between 25 and 50 ESU, 50 and 100 ESU, and greater than 250 ESU are in good financial position. The structure of these with all analyzed farms is 18%, 21.8%, 5.8% respectively. Farms to economic size between 4 and 8 ESU, 8 and 15 ESU are in fair financial position. The structure of these with all analyzed farms is accordingly 9.5% and 15%. Remaining two farms are classified in vulnerable financial position and it presents about 17.8% comparing with all analyzed farms. There was a gradual increase on D/A ratio according to farms economic size. Therefore, it is quite possible, that farms with high economic size are more risk averse than low. Low economic size farms ROE ratio is less than -5%, it tends to fail in long-term. In relation to this argument, the authors can state that economic size have influence on farms financial position.

Considering single ratio of RE/GM, all farming groups according to economic size can be classified as stable, because boundary values of ratio RE/GM are less than 25%.

Conclusions

In the survey 3 financial ratios (D/A, ROA and ROE) and financial distress measure RE/GM were used. The survey showed, that analysed Lithuanian farms are not risk averse *according to the farm size, land quality, economic size, farmer's age and type of farming*, as D/A ratio was less than 40% in all cases. Farms located in less favoured areas have marginally higher D/A ratio compared to farms located in normal areas. Farms with older than 50 years of age farmers have almost 4 percentage points smaller D/A ratio. Therefore, it is quite possible that younger farmers

are more risk averse than older ones. There was a gradual increase in D/A ratio according to the farms' economic size. Therefore, it is quite possible that farms with high economic size are more risk averse than with those with low.

Generally, the bigger is the farm size, the higher is ROE ratio. According to ROE ratio, the biggest farms (from 50 hectares) are financially stable in the short-term. High land quality, type of farming, farm's economic size, farmer's age tend to have influence on farms financial position. According to Melichar's procedure, organic farms are classified to be in fair financial position. It is very probable that the organic farm will fail, because ROE ratio is less than -5%.

All farming groups can be classified as stable according to single ratio of RE/GM. The authors can make a conclusion that rent and interest payments do not determine Lithuanian farms financial position. The main reason is that rent and interest payments are quite small compared to gross margin.

References

1. Aleknevičienė V., Aleknevičiūtė E. (2010) Ūkių finansinių rodiklių lyginamoji analizė Europos Sąjungos šalyse (Comparable Analysis of Financial Ratios of Farms in European Union Countries). *Apskaitos ir finansų mokslas ir studijos: problemos ir perspectyvos,* Akademija, Nr. 1 (7), pp. 13–19. (in Lithuanian).
2. Aleknevičienė V., Aleknevičiūtė E., Martirosianienė L. (2011) Financial Management in Lithuanian Farms: Comparative Analysis According to Farm Size and Types of Farming. *The fifth International Scientific Conference Rural Development 2011*, Akademija, Vol. 5, Book 1, pp. 16–22.
3. Cross R.M., Buccola S.T., Thomann E.A. (2009) Cooperative liquidation under competitive stress. European Review of Agricultural Economics. Available at: http://erae.oxfordjournals.org/content/36/3/369.short, 16 February 2012.
4. Dietrich J., Arcelus F.J., Srinivasan G. (2005) Predicting Financial Failure: Some Evidence from New Bruncwick Agricultural CO-OPS. Available at: http://onlinelibrary.wiley.com/doi/10.1111/j.1370-4788.2005.00275.x/abstract, 6 January 2012.
5. Florey B., Adams J., Robinson M. (2004) Figures for a Farming Future Getting Started in Farm Management Accounting. *DEFRA.* Available at: www.defra.gov.uk, 16 February 2012.
6. Franks J.R. (1998) Predicting financial stress in farm businesses. *European Review of Agricultural Economics*, 25, pp. 30–52.
7. Harrison A., Tranter R.B. (1989) The Changing Financial Structure of Farming. Available at: http://ajae.oxfordjournals.org/content/71/4/1073.full.pdf+html, 26 January 2012.
8. Hughes D.W., Richardson J.W., Rister M.E. (1984) Effects of Sustained Financial Stress on the Financial Structure and Performance of the Farm Sector. *American Agricultural Economics Association*, Dec. pp. 1115–1122.
9. Jolly R.W., Paulsen A., Johnson J.D., Baum K.H., Prescott R. (1985) Incidence, Intensity, and Duration of Financial Stress among Farm Firms. *American Agricultural Economics Association*, Dec. pp. 1107–1115.
10. Poole A.H. (1986) Farm indebtedness: Stimulus or millstone? *Farm Management* 6, pp. 69–74.
11. Ūkių veiklos rezultatai (ŪADT tyrimo duomenys) 2010 (2011) (FADN Survey Results) Lietuvos agrarinės ekonomikos institutas. Available at: http://www.laei.lt/index.php?mt=leidiniai&straipsnis=371&metai=2011, 1 March 2012. (in Lithuanian).
12. Vercammen J. (2007) Farm Bankruptcy Risk between Direct Payments and Agricultural Investment. Available at: http://erae.oxfordjournals.org/content/34/4/479.short, 6 January 2012.
13. Wadsworth J.J., Bravo-Ureta B.E. (1992) Financial Performance of New England dairy farm. Available at: http://phoenix.nal.usda.gov/bitstream/10113/34716/1/IND92017422.pdf, 1 March 2012.

PERSPECTIVE OF SUSTAINABLE FOOD CONSUMPTION IN LATVIA

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Abstract
Food consumption becomes an increasingly important topic considering global and local environmental problems as well as health issues and wellbeing of nations in general. Also in Latvia people are becoming more aware of importance of food and its direct and indirect impact on their everyday life. Therefore it is very important to evaluate sustainable aspects of food consumption and look for the barriers and drivers in order to form more sustainable consumption patterns which are based on information, knowledge and consciousness. The aim of the study is to investigate the perspective of sustainable food consumption in Latvia. The tasks of the study are:
1. to review present food consumption patterns from sustainability perspective;
2. to elucidate consumers' understandings, attitudes and behaviour towards sustainable food consumption.

The empirical research was based on the online survey with a sample of 82 women in the age group from 19-35. Descriptive statistics were used to analyze the results of the questionnaire and data obtained from Central Statistical Bureau of Latvia. The results of the study indicate the gap between positive attitudes towards sustainable food and stated purchasing behaviour. There is an obvious perspective of growth of sustainable food market if we increase the awareness of consumers regarding sustainable consumption issues.
Key words: sustainable, food, consumption, behaviour, attitudes.

Introduction

Since food belongs to the very basic needs of all living beings and is the most essential product for daily consumption worldwide, it is clearly the basics of sustainable development. Sustainable food consumption should be on the top of every national political agenda, which is striving to secure wellbeing of their nation.

According to the calculations of total carbon footprints in Latvia, food constitutes approximately 55% of households' greenhouse gas emissions (GHG) Brizga and Kudriņickis (2009), composing the largest share is composed of animal products of high carbon capacity. Moreover food endangers not only the carrying capacity of the earth but human health as well.

There is no common definition or internationally accepted criteria system for sustainability of food. Most definitions mention three dimensions of sustainability: social sustainability (i.e. people issues, such as health, food safety, quality of life and hunger), environmental sustainability (i.e. land use, energy use and gas emissions and soil pollution) and economic sustainability. One cannot speak about food sustainability without evoking a sustainable agriculture (a way of producing food and feed that is healthy for consumers and animals, does not harm the environment, is humane for workers, respects animals, provides fair wages to farmers and supports and enhances rural communities), and sustainable nutrition, defined through the following aspects: enjoyable and easily digestible foods, preferably plant-based foods, preferably minimally processed foods, organically produced foods, regional and seasonal products, products with environmentally sound packaging, and fair-trade products Lefin (2008).

As Tischner and Kjaernes (2007) underline it: 'The goal cannot be to reduce consumption of food as much as possible, but to figure out which kinds of food, produced and processed where and in what way, prepared, how and by whom, consumed, digested, with leftovers disposed off or even reused in etc. are the most sustainable options for different regions and cultures, different production systems and consumers/ citizens.'

The aim of the study is to investigate the perspective of sustainable food consumption in Latvia.

To attain the aim the following tasks are identified as relevant:

1. to review present food consumption patterns from sustainability perspective;
2. to analyze the results of survey about consumers' understandings, attitudes and behaviour towards sustainable food consumption.

The empirical research was based on the online survey with a sample of 82 women in the age group 19-35. Descriptive statistics were used to analyze the results of the questionnaire and data obtained from Central Statistical Bureau of Latvia. The methods of analysis, synthesis and logical construction were used to study the problem elements.

Materials and Methods

To draw the perspectives of sustainable food consumption in Latvia, attitudes and behaviours towards sustainable food consumption were linked together to find out the extent to which attitude is translated into purchasing behaviour. To get an insight into this the study focused on three aspects:

- how important the issue is for the consumer;
- does the consumer actively seek the more sustainable produce;

- the purchases of products identified as being more sustainable (obtained from official statistics).

To obtain the answers on two first questions mentioned above, an online survey was designed and conducted in March 2012. To measure attitudes and opinions the questionnaire was mainly containing Likert-type scales, which assumes that the strength/ intensity of experience is linear, i.e. on a continuum from strongly agree to strongly disagree, and makes the assumption that attitudes can be measured. Respondents were offered a choice of five pre-coded responses with the neutral point being 'I do not know' or 'have no opinion'.

The Likert Scale was also used to allow the individual to express the degree of their agreement or disagreement with a particular statement.

The sample for this study consisted of 82 young consumers - women in the age group from 19 to 35 years. The rationale for focusing on this population is twofold. Firstly, the women are the ones who are mainly shopping for food and serving it to their families. Secondly, the young age is chosen because this is the time, when women establish families and form their own values and attitudes towards joint consumption.

Descriptive statistics were used to analyze the results of the questionnaire and data obtained from Central Statistical Bureau. The methods of analysis, synthesis and logical construction were used to study the problem elements.

Results and Discussion

Sustainable consumption is based on a decision-making process that takes the consumer's social responsibility into account in addition to individual needs and wants. Everyday consumption practices are still heavily driven by convenience, habit, value for money, personal health concerns, hedonism, and individual responses to social and institutional norms and, most importantly, they are likely to be resistant to change.

Even though there is the evidence of growing share of ethical consumers, who are feeling responsible towards society and environment and expressing these feelings by means of their purchase behaviour, practice shows that initiatives like sustainable organic food, products free from child labour, and fair-trade products often have market shares of less than 1% Vermeir and Verbeke (2005). This is at least partly due to the attitude-behaviour gap: attitudes alone are often a poor predictor of behavioural intention or marketplace behaviour (Kraus, 1995; Ajzen, 2001).

Potential explanations are that price, quality, convenience, and brand familiarity are still the most important decision criteria (Carrigan and Attalla, 2001; Weatherell et al., 2003), while ethical factors are only effectively taken into account by a minority of consumers. This was also proved in this particular study, where 64% of respondents stated to buy the products of their favourite brand.

Hence, although consumer interest in sustainable products may be growing, sustainable food markets remain niche markets, attracting consumers with a specific profile.

A positive attitude towards sustainable products is a good starting point to stimulate sustainable consumption. Several studies concentrated on attitudes towards sustainability and sustainable consumption behaviour. In general, about 30% of the consumers have a positive attitude towards sustainable consumption These consumers claim to pay attention to ecological packaging, the origin of the food products and regularly buy sustainable organic food products. They perceive sustainable products to be better with respect to taste, quality, safety, and freshness, and to be more beneficial with respect to human health, the environment, and regional economies. A more negative attitude is found for the attributes price, appearance, convenience, and conservation. However, although people may have a positive attitude, they are largely passive in their role as consumer when it comes to supporting environmental or animal welfare improvements with their available budget (Vermeir and Verbeke, 2005).

The particular study is based on the following criteria's of sustainable food consumption:

- locally and seasonally produced food, thus reducing the consumption of energy and food miles, while storing the products and delivering to consumers;
- ecologically produced food, which includes animal welfare, biological diversity, food and the environment free from pollution of agricultural chemicals;
- reduced meat consumption, thus reducing CO_2 emissions and negative impact on the environment;
- fair trade products, which includes social fairness and care about the environment;
- reduced food waste.

All these criteria's were used to design the questionnaire in order to understand consumers' opinion, attitudes and behaviour towards sustainable food consumption.

In Table 1 the results of the questionnaire, where consumers indicate their attitudes and state their actual behaviour towards sustainable food consumption issues are shown. All aspects were rated as important by high levels of consumers but there were differences. Healthy balanced diet was rated the highest with 90% classing it as important, while the waste (37%) and

animal welfare (54%) were rated the lowest.

Most of the consumers claimed that they buy sustainable food, especially locally (52%) and in season (47%) produced vegetables and fruits as well as healthy food (56%) and production with high animal welfare standards (43%), but not as much as they would prefer to. Much smaller number of respondents replied that they really buy the food with indicated sustainability criteria. Especially low purchasing level was found for fair trade (6%) and animal welfare products (11%). It is mainly related to low understanding and information about these products as well as availability. 58% of respondents answered that they do not know anything about fair trade products, and 36% stated they have got some information, which is not enough to make an intentional choice. To make the fair trade concept more familiar the questions about products were restricted to tea and coffee, which are the main available choices in shops, but results show that it did not help to identify the concept.

Regarding animal welfare, 72% respondents replied that they have no idea how to recognize if the products (meat, eggs and milk) are produced considering animal welfare standards or not.

These numbers present an obvious gap between attitude and behaviour. Apart from the explanations about culture, values, needs and motivation, these results can be mainly interpreted with insufficient knowledge, information and availability of sustainable food products.

The results show obvious potential and perspective of sustainable food market. If consumers received more information and education regarding sustainable consumption issues, it would progress in higher sales of sustainable food products with one objection – the price should not be much higher than that of convenience food. In this study the effect of the price is not researched in details, but most of previous studies indicate its strong impact on decision to choose sustainable food products. However, only 22% of respondents stated that they look for cheapest products while shopping for food.

To emphasize the importance of information and knowledge, consumers were asked if they need more information in order to choose the environmentally friendly produced food. 82% of respondents gave a positive response.

Although the respondents of this study represented just a part of the whole Latvian population, some outcomes showed very similar results with other study conducted by DnB Nord Bank, which represents the whole Latvian population. In this particular study 58%

Table 1

Importance of sustainable food issue and stated purchase behaviour of consumers

Theme	Very important/quite important issue, % (number)	Consumers buying particular products, % (number)	Consumers buying particular products, but not as much as they would like to, % (number)
Whether food products are in season	**74** (61)	**38** (30) vegetables and fruits	**47** (37) vegetables and fruits
Whether the food products are produced in Latvia	**84** (53)	**35** (28) vegetables and fruits	**52** (42) vegetables and fruits
Whether food products comply with a healthy and balanced diet and are safe for consumption	**90** (74)	**21** (17)	**56** (46)
Whether the food has been produced ethically and socially responsible	**60** (49)	**6** (5) Fair trade tee or/and coffee	**9** (7) Fair trade tea or/and coffee
Whether animal based products have been produced to high animal welfare standards	**54** (44)	**11** (9) milk, eggs and meat	**43** (35) milk, eggs and meat
Whether the food item has been produced ecologically and with respect to the environment	**72** (58)	**14** (11)	**58** (53) Sometimes buying
Whether the package of the product is recyclable	**37** (30)	-	-

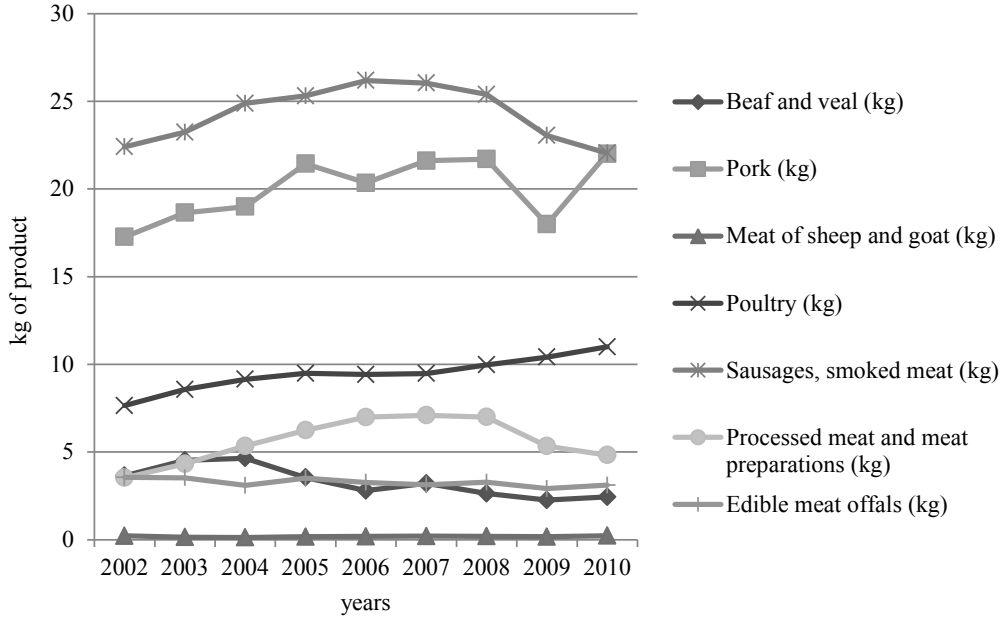

Figure 1. Consumption of meat and meat products in average per household member per year in kg (from 2002 to 2010).

Source: Central Statistical Bureau of Latvia and authors' compilation.

of respondents answered that they sometimes buy ecologically produced food and 14% said they do it on regular basis, in the survey of DnB Nord barometer (2010) these numbers are - 52% buying sometimes, 19% - buying regulary.

Calculations of Ecological footprint of food show that the diet of an average Latvian consumer annually creates from 850 to 950 kg of CO_2. Most (330 kg) of the emissions are associated with the consumption of meat products, in the second place with 110 kg of CO_2 are milk products, followed by vegetables (85 kg of CO_2). Bread and pastries produce 70 kg of CO_2, consumed eggs cause 55 kg of CO_2, but potatoes only 16 kg of CO_2 per year. These figures depend on the amount of consumed food and carbon intensity of the product that can vary considerably between various commodities (Brizga and Dzene, 2011).

In order to explore the sustainability character of food consumption of Latvian consumers, statistical data of food consumption with the biggest impact on the environment was used, i.e. meat and meat products as well as fruits and vegetables, which on other side, usually meet the sustainability conditions.

In Figure1 more positive tendencies towards sustainable food consumption can be observed. First of all the consumption of sausages and smoked meat has been decreasing sharply since 2007. It is mainly positive tendency due to health dimension of sustainable food – these products are high in content of salt and saturated fat. 85% of respondents responded that they are trying to follow the principles of healthy diet. 68% of respondents claimed that they are trying to limit the content of salt and saturated fat (77%) in their food. Awareness about healthy food is obviously growing especially among women.

Secondly consumption of beef is decreasing, what is more important from ecological perspective. Beef has the highest CO_2 emissions among other livestock, and also needs more agricultural land and use of water.

From this statistical quantitative data nothing more about other dimensions of sustainable food is possible to infer.

In the last 8 years (2002-2010) vegetable consumption has been decreasing sharply (see Figure2) and the future trend line as well as R-squared value shows that it is still going to decrease. Partially it can be explained with decreased consumption of potatoes (from 115 kg to 87 kg per capita per year), which is the main vegetable in totally consumed amount of vegetables. From environmental point of view this decrease is not much reducing CO_2 emissions, but from health perspectives it can be evaluated as a positive trend, because the daily nutrition is gradually becoming more diversified. 88% of respondents answered that they are trying to eat fresh vegetables and fruits as much as possible, and this is considered to be a part of a healthy diet; however, it cannot be observed from statistical data, because in all categories vegetable consumption is reduced.

The decrease of fruit consumption is assessed as more negative aspect if examining the source, the decrease comes from. Since 2002 mainly the consumption of apples (from 19 kg to 12 kg per capita) has decreased, but at the same period the consumption

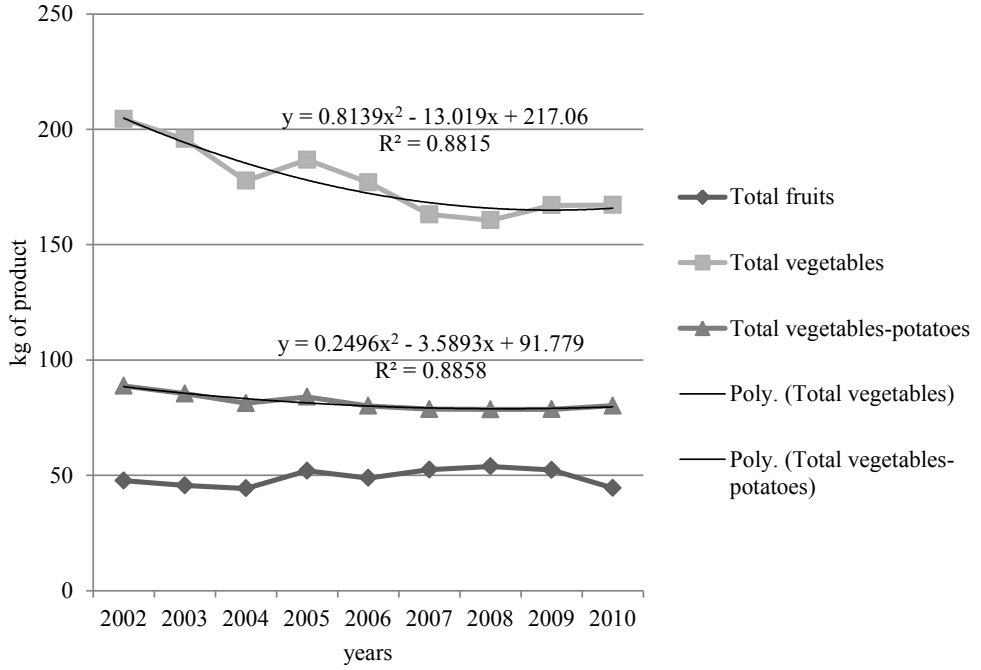

Figure 2. Consumption of vegetables, fruits and its products in average per household member per year in kg (from year 2002 to 2010).

Source: Central Statistical Bureau of Latvia and authors' compilation.

of exotic fruits such as oranges, tangerines and bananas has doubled. This is opposite tendency of sustainable consumption. It increases food miles, i.e. greater CO_2 emissions as well, and it does not support local producers and state economy itself. Unfortunately, fair trade fruits are not available in Latvia's supermarkets, meaning that by eating imported fruits, consumers do not support sustainable consumption in any of sustainability aspects.

85% of respondents agreed that buying locally and seasonally produced vegetables and fruit; they are also taking care of the environment, thus showing good understanding of the issue.

Conclusions

1. The attitudes towards sustainable food consumption among selected respondents were highly positive and noted as important. Healthily balanced diet was rated the highest with 90% classing it as important, while the waste (37%) and animal welfare (54%) were rated the lowest.
2. Evaluating the consumer behaviour towards sustainable food consumption, there is an obvious gap between attitudes and stated behaviour. The positive attitude does not result in the same rate of purchasing behaviour. These results can be interpreted by insufficient knowledge and availability of sustainable food products.
3. Especially low purchasing level is for fair trade (6%) and animal welfare products (11%), that shows the importance of provision of information in raising the awareness of particular issue. 58% of respondents responded that they do not know anything about fair trade products and 36% stated they have some knowledge about it, but it is insufficient to make an intentional choice.
4. 72% respondents answered that they have no idea how to recognize if the products (meat, eggs and milk) are produced considering animal welfare standards.
5. Statistical data of meat consumption shows positive tendencies towards healthy consumption, but data about fruit consumption reflects the growing share towards consumption of imported commodities, that is considered as unsustainable. 88% of respondents state that they try to eat fresh fruits and vegetables as much as possible, that contradicts with decreasing numbers in statistical data. It can be explained with particular group of respondents of this study.
6. The results of the study show a growing perspective of sustainable food market share. Clearer and more understandable information is delivered to consumers, especially women, faster the shift to more sustainable consumption patterns is expected to take place.

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References

1. Ajzen I. (2001) Nature and Operation of Attitudes. *Annual Review of Psychology*, 52, pp. 27–58.
2. Brizga J., Dzene S. (2011) Environmental Burden of Food Consumption in Latvia. In: *Proceedings of the International Scientific Conference: Rural Development 2011*, 5 (1), Aleksandras Stulginskis University, Kaunas, Lithuania, pp. 79–83.
3. Brizga J., Kudreņickis I. (2009) Household climate impact in Latvia: measuring carbon footprint. In: Technologies of environment and climate. *Proceedings of international scientific conference*, Riga Technical University, Latvia, pp. 34–40.
4. Carrigan M., Attalla A. (2001) The Myth of the Ethical Consumer - Do Ethics Matter in Purchase Behavior. *Journal of Consumer Marketing*, 18(7), pp. 560–577.
5. Central Statistical Bureau of Latvia (CSB) (2012) Consumption of food products average per household member per year. Available at: http://data.csb.gov.lv/Dialog/varval.asp?ma=MB0160a&ti=MBG16%2E+CONSUMPTION+OF+FOOD+PRODUCTS+AVERAGE+PER+HOUSEHOLD+MEMBER+PER+YEAR&path=../DATABASEEN/Iedzsoc/Annual%20statistical%20data/Household%20budget/&lang=1, 2 March 2012.
6. DnB Nord Latvijas barometrs (2010) Pārtikas produktu patēriņš (Consumption of food products). Available at: http://www.dnb.lv/static/files/301.dnb-nord-latvijas-barometrs-24.pdf, 4 February 2012.
7. Kraus S.J. (1995) Attitudes and the Prediction of Behavior – a Meta-Analysis of the Empirical Literature. *Personality and Social Psychology Bulletin*, 21(1), pp. 58–75.
8. Lefin A.L. (2008) Food consumption and sustainable development: an introduction. Available at: http://consentsus-project.pbworks.com/f/SustFoodCons_patterns.pdf, 2 March 2012.
9. Tischner U., Kjaernes U. (2007) Sustainable consumption and production in the agriculture and food domain. In Lahlou S., Emmert S. (eds.) Proceedings of the Sustainable Consumption Research Exchange. *Proceedings: SCP cases in the field of food, mobility and housing*, Paris, pp. 201–237.
10. Vermeir I., Verbeke W. (2006) Sustainable Food Consumption: Exploring Consumer 'Attitude – Behavioral Intention' Gap. *Journal of Agricultural and Environmental Ethics*, 19, pp. 169–194.
11. Weatherell C., Tregear A., Allinson J. (2003) In Search of the Concerned Consumer: UK Public Perceptions of Food, Farming and Buying Local. *Journal of Rural Studies*, 19(2), pp. 233–244.

ENTREPRENEURIAL ACTIVITY IN KURZEME REGION

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Abstract
Entrepreneurial activity in various regions of Latvia is one of the most actual topics for politicians at many levels. The aim of this paper is to characterize entrepreneurial activity in the Kurzeme Region in the context of municipalities analysing the accessible statistical data. The entrepreneurial activity in the Kurzeme Region is analyzed both in general and in the context of municipalities in this paper. Analysing accessible statistical data, one can draw a conclusion that the entrepreneurial activity in the Kurzeme Region is not even. It testifies that the factors which influence entrepreneurial activity development in some areas are to be searched at the level of municipalities. In addition, the analysis of data specifies various correlations. For example, the smallest number of merchants per 1000 inhabitants in Kurzeme region is in relatively small border municipalities, but higher results are in large cities and local authorities who comprise larger cities or in municipalities which border with larger towns. It is similarly discovered that in Kurzeme region there is a smaller amount of self-employed persons in local authorities with a large number of merchants per 1000 inhabitants and vice versa. There are also exceptions, further research is necessary to justify such correlations.
Key words: Municipalities, self-employed persons, merchants, farm and fish hatchery, individual merchants.

Introduction

Discussions about entrepreneurial activity and economy development in regions of Latvia have become especially topical under the influence of a few factors. The socio-economic situation characterizing data testifies an imbalanced development in regions of Latvia. Development characterizing pointers in Rīga and Pierīga statistical regions are considerably higher than in Kurzeme, Zemgale, Vidzeme and Latgale regions. Also, if the development differences are not so remarkably visible in Kurzeme, Zemgale and Vidzeme, then the socio-economic conditions are substantially worse in the Latgale Region. The second factor, which influences discussions about entrepreneurial activity development not only in the context of regions, but also at the level of local authorities, is the Administrative territorial reform of Latvia ceased in 2009.

In spite of the fact that each local authority - both rural and urban - is different, development issues, as well as entrepreneurial activity and economic development, are quite often observed at the regional level. Thinking of the general development of one state, the regional aspect and the counterbalanced development of regions are among the primary questions. This issue raises a question both for urban and rural areas development, because, as R. C. Feiock and J. H. Kim (2000) mark, the economic development is considered to be an area of attractiveness of basic criterion, and local elected public servants should react to the concrete area's economy requirements. A necessity to examine entrepreneurial activity development issues on a regional and local scale is also confirmed by E. Santarelli and M. Vivarelli (2007), which stress the opinion that all positive factors, that influence entrepreneurial activity and the appearance of new enterprises, are to be searched at the regional level, because observations testify that entrepreneurial activity differs in various geographical areas. Therefore, entrepreneurial activity development in local authorities has to be examined both separately and in the context of regional development and competitiveness.

Regional differences, development of regions, competitiveness of regions, entrepreneurial activity development in regions are often investigated issues (Vaidere et al., 2006; Zvirgzdiņa, 2007; Judrupa and Šenfelde, 2008; Čingule, 2009; Krastiņš and Locāne, 2009; Zvirbule-Bērziņa and Gruziņa, 2011). However, the entrepreneurial activity development issues in different regions in Latvia are rarely examined in the context of municipalities. The development level can be diametrically opposite even in two nearby municipalities, thus, inducing a search for the reasons of differences. Data comparing analysis at the level of municipalities can give substantial information to both local authorities, producing local development strategies and various industries development plans, and politics planners at the regional level. Therefore, the author analyses entrepreneurial activity in the Kurzeme Region, separately examining the situation in municipalities. **The aim** is to characterize entrepreneurial activity in the Kurzeme Region in the context of municipalities analysing the accessible statistical data. The following **tasks** are executed to reach the aim: the scientific literature regarding entrepreneurial activity development differences in various areas is analysed; statistical data on entrepreneurial activity in the Kurzeme Region in general and in its municipalities is summarized and analysed.

Materials and Methods

The scientific literature and research on entrepreneurial activity development differences in various areas have been summarized and analysed in the beginning to find out whether and why entrepreneurial activity issues are examined both at regional and local authorities' level and which are the main differences in entrepreneurial activity development in various places, including rural areas and towns.

The data of the Central Statistical Bureau of Latvia on the the number of active merchants and self-employed people, as well as on the number of active merchants in the Kurzeme Region by their size and the number of active enterprises by size in all Latvia regions were used in the research. During the research (March of 2012) only provisional data is available in the Central Statistical Bureau of Latvia for the year of 2010 that was also used in this research. Municipal statistical data in the section is available in the Central Statistical Bureau of Latvia only for the years of 2009 and 2010 due to the closed in 2009 Administrative territorial reform of Latvia. Therefore, it was not possible to determine tendencies for the longer period of time. Lursoft data on the enterprises and merchants registration dynamics is also used in the research.

The following methods are used in the research: a monographic method, analysis and synthesis, logic – construction method, time series analysis.

Results and Discussion

In the Kurzeme Region there are 18 municipalities – Aizpute, Alsunga, Brocēni, Dundaga, Durbe, Grobiņa, Kuldīga, Mērsrags, Nīca, Pāvilosta, Priekule, Roja, Rucava, Saldus, Skrunda, Talsi, Vaiņode and Ventspils municipality, as well as of 2 cities of the state importance – Liepāja and Ventspils. The size of municipalities both in the number of inhabitants and in terms of space is very different.

Entrepreneurial activity development in rural areas and in small towns also plays a substantial role in the even state development. The most important reasons for the uneven economic development of areas are various distances from markets and highways, communication and transport expenses related to that, as well as various levels of infrastructure (Slavinska, 2007). Other researchers (Ķusis et al., 2008) also specify, that a crucial circumstance in promoting entrepreneurial activity is the infrastructure and among entrepreneurial activity's delaying factors in small towns the authors mention a lack of territory, lack of initiative and the unfinished Administrative territorial reform of Latvia (it was completed on 1 July, 2009 – author's footnote). In turn, R. Zvirgzdiņa and A. Auziņa (2008) suppose that the successful entrepreneurial activity development in rural areas can be provided, if the socio-economic features and interests of each territorial unit, management traditions are taken into account and modified and entrepreneurial activity based on the resources of the corresponding environment is created.

In turn, entrepreneurial activity is often concentrated in a narrow and specialized sphere in small towns and medium-size towns giving benefits to the whole town, but the town's economic future is closely related to the concrete industry, which town's merchants have specialized in (Wolfe, 2008). One of the most substantial tendencies in entrepreneurial activity now is to search for innovative products, to introduce various innovations both in production and in service processes. Therefore, entrepreneurial activity development in the region should also be planned from this perspective. Traditionally, regional centres are more active regarding innovations; however, it is essential to develop the innovative entrepreneurial activity also in rural areas (Coronado et al., 2008).

Analysing the number of economically active units in the market sector (Table 1) for all statistical regions in Latvia, it is evident that, for example, Rīga Region is considerably dominated by commercial companies (Co Ltd's and JST's) – they constituted 73.4% in 2010, in turn, there was only 0.1% of farms and fish hatcheries. Also the amount of self-employed persons, in comparison to other regions, is noticeably less in the Rīga Region - only 22.6%. The situation in the Pierīga statistical region is also similar - 46% is

Table 1

Number of economically active statistical units of market sector in planning regions in 2010, %

Region	Self-employed	Individual merchant	Commercial company	Farm and fish hatchery
Rīga	22.6	3.9	73.4	0.1
Pierīga	38.6	6.0	46.0	9.3
Vidzeme	45.6	6.2	27.6	20.6
Kurzeme	46.1	8.3	30.0	15.7
Zemgale	42.6	8.8	29.5	19.2
Latgale	52.4	7.9	23.3	16.4

Source: provisional data of Central Statistical Bureau of Latvia

commercial companies. It is explained by the fact that there is the largest economic activity on the whole in Rīga and Pierīga regions, as well as a larger scale of transactions.

It is characteristical for the Kurzeme Region that the largest part of economically active units are self-employed persons (similarly also in Vidzeme, Zemgale and Latgale) - 46.1%, which is the second highest parameter after the Latgale Region (52.4%). There are also less farms and fish hatcheries in the Kurzeme Region, comparing to Vidzeme, Zemgale and Latgale, - 15.7%. At the same time, there are 30% of commercial companies in the Kurzeme Region, being the third highest parameter after Rīga and Pierīgas statistical regions.

Entrepreneurial activity scale that is chosen by a merchant, relying on his possibilities and potential demand in the market, can be various. If entrepreneurial activity is targeted only to earn the living for oneself and family, then it can be a small enterprise or even the enterprise without any employees. It is discussed in the recent years that the increase in the amount of self-employed persons can impede entrepreneurial activity development. R. Baptista and A. R. Thuric (2007) specify that, on the one hand, the increase of unemployment level stimulates the amount of self-employed people, on the other hand - a high level of self-employment can create a decrease of entrepreneurial activity on the whole, which can enlarge unemployment level in the longer period of time. A. Zvirbule-Bērziņa and Z. Gruziņa (2011), investigating development of small and medium enterprises in regions of Latvia, drew a conclusion, that the number of small and medium enterprises can influence regional GDP, but it has no or little influence on employment level.

However, the author supposes that becoming a self-employed person is already the first step in the direction of entrepreneurial activity meaning that a person has a desire to work for oneself, take responsibility, develop his services or manufacture a product. Practice testifies, that with the beginning of activity as a self-employed person, the demand for the product created by this person can increase and, accordingly, a necessity for activity expansion can appear. It, certainly, requires additional knowledge and skills of organizing business that a self-employed person doesn't always have. The author supposes, therefore, that purposeful support and educational steps right for self-employed people can be an instrument for business activities enlargement.

The largest part of enterprises in the Kurzeme Region is micro-enterprises (Table 2). Besides, the number of micro-enterprises increased in 2009 and 2010. If they were 12064 in 2005, then in 2009 and 2010 they were, accordingly, 15018 and 15923. It is explained with the period of the economic downslide, as well as it was more actively thought about various facilitations for new merchants. At the same time, the volume of small and medium enterprises slightly diminished in recent years (2009 and 2010). In turn, the amount of large enterprises shrank from 33 enterprises in 2005 to 24 enterprises in 2009 and 2010.

For detailed understanding of how entrepreneurial activity sector shapes in the Kurzeme Region, it is also necessary to analyse the statistical data of municipalities. It has become an especially topical economy and entrepreneurial activity question in the context of local authorities after the Administrative territorial reform of Latvia, because one of its main aims was to create local authorities capable of economical development.

Possibilities of local authorities to influence entrepreneurial activity environment are formed by their role and tasks in executing strategy of the territorial planning and development, because they own a part of local resources, for example, land, apartments (Grīnberga and Nešpors, 2001). S. Čapkova (2005) stresses that the development of local economy is generally linked with the strategy with which public servants of local authorities and institutions use the resources that are at their service both to preserve and create new jobs and promote and speed up business activities.

In order to determine registration of enterprises activity in the Kurzeme Region, the author used

Table 2

Number of economically active statistical units of market sector in Kurzeme by size groups, 2005-2010

Size group	Number of enterprises during 2005-2010					
	2005	2006	2007	2008	2009	2010
Micro	12064	14108	15206	14666	15018	15923
Small	1077	1105	1225	1207	989	920
Medium	227	252	257	259	205	207
Large	33	31	35	31	24	24

Source: created by the author, based on data of Central Statistical Bureau of Latvia

Table 3

Changes in the number of business registration dynamics in Commercial Register and Enterprise Register, 2007-2011

Municipality/Year	Count of enterprises	Annual growth			
	2007	2008	2009	2010	2011
Alsunga	6	-2	3	-2	-1
Roja	18	-7	-6	7	-4
Rucava	8	-3	-2	1	11
Nīca	18	-9	1	2	-1
Dundaga	9	-6	2	10	1
Vaiņode	2	4	-5	8	0
Aizpute	27	-8	14	-13	17
Grobiņa	29	2	-14	7	10
Kuldīga	78	4	-15	23	18
Pāvilosta	13	-7	0	0	9
Priekule	13	-2	2	-5	6
Saldus	138	-52	7	4	22
Skrunda	23	-14	1	3	3
Talsi	125	-33	-30	51	-9
Durbe	6	3	3	-1	6
Brocēni	22	-3	2	5	7
Ventspils municipality	38	-9	2	5	7
Liepāja	413	-100	-48	76	87
Ventspils	188	-30	-31	14	3

Source: computed by the author by data of Latvian IT company Lursoft.

data both from the Enterprise Register and the Commercial Register for the period of time from 2007 to 2009. Since, obviously, the amount of the registered enterprises of state importance cities and in the larger municipalities is greater than in smaller ones, the author used the absolute chain sequence in calculations.

As it can be seen in Table 3, negative enterprises registration dynamics can be observed in almost all municipalities in 2008. The increase in the amount of enterprises registration is observed in none of municipalities in the period of time from 2007 to 2010. But from 2009 to 2011 there is a positive, increasing tendency in the enterprise registration dynamics. An insignificant fall is reported only in Alsunga, Roja, Nīca and Talsu municipalities in 2011. Most new enterprises are registered in Liepāja and Ventspils, as well as in Saldus and Talsi municipalities, which are the largest municipalities in terms of the number of inhabitants in the Kurzeme Region. We can conclude that generally local authorities' entrepreneurial activity in the Kurzeme Region stabilized again in the last two years.

It can be supposed, that a larger number of enterprises is registered in municipalities with larger numbers of population – indeed, the more inhabitants, the more enterprises. The author presumes that it indicates that in the larger in terms of population municipalities entrepreneurial activity in terms of amount of enterprises is totally higher, because there are, naturally, more people with business abilities in areas with more human resources, as well as there is more attractive and larger market for services, that influences the number of enterprises. In comparison to large cities and municiapalities, local authorities with a small number of inhabitants should draw special attention to entrepreneurial activity stimulation, spreading purposeful activities of human resources education, creating an effective management system in the municipality council with a goal to develop entrepreneurial activity sector in the municipality.

In order to make the data on entrepreneurial activity in the Kurzeme Region comparable, the author calculated the number of the active merchants in each local authority per 1000 inhabitants, because their number in the region is sharply different (Table 4).

As we can see in Table 4, the most (29) active merchants per1000 inhabitants and, accordingly, the largest economic activity is in the Roja municipality, in turn, there are 28 merchants per 1000 inhabitants in both towns of Liepāja and Ventspils. There are 27 merchants per 1000 inhabitants in Nīca, Mērsrags and Saldus municipalities although, for example, the number of population in Nīca and Mērsrags municipalities and Saldus municipalities differ

Table 4

The number of merchants per 1000 inhabitants in the municipalities of Kurzeme

Municipality	Active merchants, 2010	Inhabitants	Number of merchants per 1000 population
Roja	116	3967	29
Liepāja	2152	76570	28
Ventspils	1064	38645	28
Mērsrags	44	1638	27
Nīca	96	3578	27
Saldus	686	25584	27
Talsi	786	31192	25
Kuldīga	533	24849	21
Grobiņa	185	9361	20
Ventspils municipality	237	12135	20
Skrunda	91	5305	17
Alsunga	25	1470	17
Pāvilosta	48	2847	17
Dundaga	71	4237	17
Brocēni	102	6225	16
Aizpute	148	9265	16
Rucava	27	1811	15
Durbe	42	3047	14
Vaiņode	28	2609	11
Priekule	62	5833	11

Source: authors' calculation by data of Central Statistical Bureau of Latvia (provisional data of 2010) and provisional data of Population Population Census (2011).

considerably. Convincing results are in the small in terms of the amount of population Roja, which induces searching for reasons of such a large number of enterprises in this area, because, for instance, in the review "Regional Development In Latvia, 2010" the data testifies that in the period from 2006 to the beginning of 2011 the amount of Roja population diminished even more rapidly than on the average in municipalities of Latvia. So, the answer to the question, why there is a larger entrepreneurial activity in one area than in another, should be searched not only in connection with the amount of population. The fewest active merchants per 1000 inhabitants are in Vaiņode and Priekule municipalities - 11, which are followed by Durbe municipality with 14 and Rucava municipality with 15 merchants per 1000 inhabitants. Vaiņode, Priekule and Rucava municipalities are border municipalities with a relatively small number of population. Due to calculations, it is obvious that more decent results are in local authorities, which are in larger towns or border with large cities, for example, Nīca and Grobiņa municipalities border with Liepāja. The results induce to investigate more in depth, which are the entrepreneurial activity influencing factors in a certain area.

Since the largest part (46.1%) of the economically active statistical units in the Kurzeme Region are self-employed persons (Table 1), the author also examined the number of self-employed persons in the division of local authorities. Data on municipalities is accessible only for 2009 and 2010, whereas, provisorial results - for 2010.

As we can see in Table 5, the largest amount of self-employed persons in 2010 is observed in Liepāja (1519), Talsi (1097) and Kuldīga (863) municipalities. In turn, the fewest number of self-employed people is registered in Mērsrags (17) and Roja (50) municipality. Comparing to 2009 and 2010 the number of self-employed persons increased almost in all local authorities, except Brocēni, Roja and Mērsrags municipalities, where the amount of self-employed persons diminished accordingly by 11 and 20 and 4 persons. Also, the number of self-employed persons is especially high in the cities of state importance (in Liepāja and Ventspils), as well as in the largest Kurzeme Region municipalities - Talsi, Saldus and Kuldīga. However, analysing the data on the amount of self-employed persons per 1000 inhabitants in each local authority (Table 5), it is evident that the highest pointers are in Rucava (75) and Priekule (62) municipalities, where, for example, the number of merchants was relatively one of the lowest (Table 4).

In turn, the fewest numbers of self-employed persons per 1000 inhabitants are in Mērsrags and Roja

Table 5

Self-employed persons in municipalities of Kurzeme region, 2009-2010

Municipality/year	2009	2010	Annual growth	Self-employed persons per 1000 inhabitants, 2010
Liepāja	1380	1519	139	20
Ventspils	768	823	55	21
Aizpute	376	425	49	46
Alsunga	59	69	10	47
Brocēni	182	171	-11	27
Dundaga	102	116	14	27
Durbe	151	180	29	59
Grobiņa	255	308	53	33
Kuldīga	739	863	124	35
Nīca	195	212	17	59
Pāvilosta	119	142	23	50
Priekule	310	363	53	62
Roja	70	50	-20	13
Mērsrags	21	17	-4	10
Rucava	110	136	26	75
Saldus	846	850	4	33
Skrunda	132	153	21	29
Talsi	1009	1097	88	35
Ventspils municipality	276	304	28	25
Vaiņode	68	74	6	28

Source: authors' calculation by data of Central Statistical Bureau of Latvia (provisional data of 2010) and provisional data of Population Census (2011).

municipalities, Liepāja and Ventspils, where there are the highest parameters calculating the number of merchants per 1000 inhabitants. The choice of activity form and scale can be also related to the selected activity's industry. Usually, for example, artisans, beauty specialists, consultants choose to register their activity as self-employed person's status. Therefore, the choice of form is also examined in connection with the more developed industries in the municipality. These results allow realizing each local authority's entrepreneurial activity both on the whole and for the selected activity form and, accordingly, scale. It also raises questions about the influence of types of entrepreneurial activity on the economic indicators. Similarly, a necessity appears to go into detail to investigate factors that influence entrepreneurial activity in local authorities in the Kurzeme Region.

However, despite the entrepreneurial activity results and their influence on the economic pointers, there are enterprising people in the core of entrepreneurial activity development both in rural areas and in towns, who make a decision to start entrepreneurial activity; therefore, the question, how to motivate the inhabitants to undertake a risk to transform from an employee into a self-employed person, is one of most substantial, because entrepreneurial activity in a certain area depends right on it. Only afterwards the question about a kind and scale of entrepreneurial activity that create the largest economic effect follows. Therefore, it is equally important to understand, the scale of entrepreneurial activity potential in each local authority, because the statistical data do not represent people, who only think about starting entrepreneurial activity or are ready to do it.

Conclusions

1. Entrepreneurial activity of local authorities in the Kurzeme Region stabilized in 2010 and 2011, though substantial differences are observed among local authorities. It testifies an uneven entrepreneurial activity development in the Kurzeme Region in general.
2. Calculating the number of merchants in each local authority in Kurzeme region per 1000 inhabitants, we can conclude that the lowest parameters are in border municipalities with a relatively small number of population, but higher results are in large cities and in local authorities, which are included in large cities or border with them. However, there are also exceptions that induce further and more thorough investigation, on influencing factors of entrepreneurial activity in each local authority.
3. In the Kurzeme Region local authorities which have high parameters in terms of the numbers of

merchants per 1000 ihnabitants are characterized by the low numbers of self-employed persons per 1000 inhabitants and vice versa – local authorities with a high number of self-employed persons have small numbers of merchants.
4. Self-employed persons along with owners of small enterprises form a society group with larger business potential than, for example, employees and purposeful supporting activities and education provided to this group from local authorities can help to create entrepreneurial activity on a larger scale.
5. Esspecially, authorities with a small number of inhabitants should draw a particular attention to entrepreneurial activity stimulation, spreading purposeful activities of human resources education, creating a management system in the municipality with a goal to develop entrepreneurial activity in the municipality.

References

1. Baptista R., Thuric A.R. (2007) The relationship between entrepreneurship and unemployment: Is Portugal an outlier? *Techological Forecasting and Social Change*, 74, pp. 75–89.
2. Coronado D., Acosta M., Fernandez A. (2008) Attitude to innovation in peripheral economic regions. *Research Policy*, 37, pp. 1009–1021.
3. Čapkova S. (2005) Local Government and Economic Development. In: *Local Government and Economic Development*, Budapest, Open Society institute, pp. 3–19.
4. Čingule S. (2009) Regional Development and Economic Potential of the Counties of Latvia, *Economic Science for Rural Development*, 19, pp. 294–306.
5. Ekonomiski aktīvās tirgus sektora statistiskas vienības pa lieluma grupām un statistiskajiem reģioniem. (Number and proportion of economically active statistical units of market sector in Latvia by size groups). (2005-2010) Available at: http://data.csb.gov.lv/Dialog/varval.asp?ma=SR0041&ti=SRG041%2E+EKONOMISKI+AKT%CEV%C2S+STATISTIKAS+VIEN%CEBAS+SADAL%CEJUM%C2+PA+LIELUMA+GRUP%C2M+UN++STATISTISKAJIEM+RE%CCIONIEM&path=../DATABASE/uzreg/Ikgad%E7jie%20statistikas%20dati/01_skaits/&lang=16, 10 March 2012 (in Latvian).
6. Ekonomiski aktīvās tirgus sektora statistikas vienības statistiskajos reģionos, republikas pilsētās un novados. (Number of economically active statistical units of market sector in regions, cities and municipalities). (2009-2010) Available at: http://data.csb.gov.lv/Dialog/varval.asp?ma=SR0011&ti=SRG011%2E+EKONOMISKI+AKT%CEV%C2S+STATISTIKAS+VIEN%CEBAS+STATISTISKAJOS+RE%CCIONOS%2C+REPUBLIKAS++PILS%C7T%C2S+UN+NOVADOS&path=../DATABASE/uzreg/Ikgad%E7jie%20statistikas%20dati/01_skaits/&lang=16, 11 March 2012 (in Latvian).
7. Feiock R.C., Kim J.H. (2000) Form of Government, Administrative Organization, and Local Economic Development Policy. *Journal of Public Administration Research and Theory,* 11, pp. 29–49.
8. Grīnberga D., Nešpors V. (2001) Pašvaldību ietekme uz uzņēmējdarbības vidi, *Ekonomisko un sociālo attiecību transformācija: procesi, tendences, rezultāti. (Transformation of Economic and Social Relations: Processes, Tendencies and Results).* 126–132. lpp. (in Latvian).
9. Iedzīvotāju skaits Latvijā, statistiskajos reģionos, republikas pilsētās un novados. (Number of inhabitants in Latvia, regions, cities and municipalities). (2011) Available at: http://data.csb.gov.lv/DATABASE/tautassk_11/2011.gada%20tautas%20skait%C4%AB%C5%A1anas%20provizoriskie%20rezult%C4%81ti/2011.gada%20tautas%20skait%C4%AB%C5%A1anas%20provizoriskie%20rezult%C4%81ti.asp., 10 March 2012 (in Latvian).
10. Judrupa I., Šenfelde M. (2008) Application of the ranking method in the evaluation of regional competitiveness in Latvia. *Economics & Business,* 17, pp. 37–45.
11. Krastiņš O., Locāne V. (2009) Teritoriju attīstības līmeņa un tā izmaiņu sakarības. (Coherence with Level of Territory Development and Changes in it). *Statistiskas zinātnisko pētījumu rezultāti: Zinātniskie raksti.* Rīga: LR Centrālās statistikas pārvalde, 88–97. lpp. (in Latvian).
12. Ķusis J., Krūzmētra Ž., Bite D. (2008) Pašvaldību stratēģijas teritorijas ilgtspējīgā attīstībā. (Strategies of Local Municipalities for Sustainable Development of Territory). *Economic Science for Rural Development,* 15, 88–94. lpp. (in Latvian).
13. Development of Regions in Latvia (2010) Available at: http://www.vraa.gov.lv/uploads/Development_of_Regions_in_Latvia_2010_web_ENG.pdf, 14 March 2012.
14. Slavinska I. (2007) Latvijas pašvaldības loģistikas aspektā. (Minicipalities of Latvia in Logistics aspect). *Economic Science for Rural Development,* 197–203. lpp. (in Latvian).
15. Uzņēmumu reģistrēšanas un likvidēšanas dinamika pa gadiem Komercreģistrā un Uzņēmumu reģistrā pa pilsētām un novadiem. (Dynamics of Company Registration and Liquidation in Commercial Register and

Company Register by Years Towns and Regions). (2007-2011) Available at: http://www.lursoft.lv/lursoft-statistika/Statistika-Latvijas-novadu-pilsetu-griezuma&id=515, 8 March 2012.

16. Vaidere I., Vanags E., Vanags I., Vilka I. (2006) *Reģionālā politika un pašvaldību attīstība Eiropas Savienībā un Latvijā. (Regional Politics and Development of Municipalities in the EU and Latvia).* Rīga: Latvijas Universitātes Akadēmiskais apgāds. 295 lpp. (in Latvian).
17. Zvirgzdiņa R., Auziņa A. (2008) Uzņēmējdarbības uzsākšanu kavējošie faktori lauku teritorijās. (Factors Impeding the Start of Etrepreneurship in Rural Areas). *Economic Science for Rural Development,* Nr. 15, 289–295. lpp. (in Latvian).
18. Zvirbule-Bērziņa A., Gruziņa Ž. (2011) Development of MSMEs in the Regions of Latvia, *Economic Science for Rural Development,* 26, pp. 246–251.
19. Zvirgzdiņa R. (2007) Uzņēmējdarbība un tās attīstības iespējas Latvijas reģionos. (Business and defelopment posibilities at Latvia's reģions). *Economic Science for Rural Development*, 12, 184–191. lpp. (in Latvian).
20. Wolfe D.A., Bramwell A. (2008) Innovation, creativity and governance: Social dynamics of economic performance in city-region**s.** *Innovation: Management, Policy & Practice,* 10, pp. 170–182.

ECONOMIC CALCULATION OF SHORT ROTATION WILLOW PLANTATIONS IN LATVIA

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Abstract
Short rotation forests (SRF) can be used for biomass production for energy applications in Latvia. Establishment of plantations could be one of possibilities how to reach targets of renewable energy resource (RES) consumption of 40% in 2020. In Latvia's conditions, one of most suitable species that could be used for SRF is willow *(Salix sp.).* Abandoned agricultural lands are suitable for establishment of plantations. Productivity of 8 oven- dried tons (ODT) ha^{-1} $year^{-1}$ can lead to Rate of Return (IRR) of 17.1% and Net Present Value (NPV) 1099 Latvian Lats (LVL) if the biomass price is 33 LVL ODT^{-1}. Establishment, harvesting and transporting costs account for 88% of the total cost of production. Price of wood chip and fuel plays the most important role in economics of plantation.
Key words Short-rotation plantations, coppice, willow, plantation forestry, plantation economics.

Introduction

In the European Union, biomass is 2/3 from renewable resources clearly indicating an upward trend (Jossart, 2006). In 2009, Latvia's renewable energy sources (RES) share of total energy consumption was 27.5% (Latvian energy in figures, 2011), while the target established for Latvia according to Directive 2009/28/EC (2009) is set to be 40% in 2020. In future, demand for renewable resources in electricity production and heat production will increase. One possibility to respond to the growing demand is to establish short-rotation forestry (SRF) plantations. The most common species in Northern Europe and also most suitable ones for SRF are willow (*Salix*) and aspen (*Populus*) (Hall and House, 1994). According to Central Statistical Bureau of Latvia (CSP), in 2010 there were 2,430.000 ha of agricultural lands, of them untreated areas – 368,900 ha, unmanaged areas – 316,341 ha, naturally afforested areas – 49,710 ha (Lazdins, 2011). One of possibilities to improve economic value of abandoned agriculture lands are SRF plantations; according to present- day laws, harvesting of plantations is possible when it is the most profitable, and it is also possible to revert the land to agricultural production if it is economically cost-effective at that time (Lazdina, 2009). Establishment of willow plantations leads to reduction of environmental pollution, because willows are much more effective than most of other crops in absorbing cadmium and other heavy metals from soil (Danny Harvey, 2010). They diversify the rural landscape and show positive CO_2 balance (Gonzalez-Garcia et al., 2012). The average yield of plantations in southern part of Europe is 9 oven dried tons (ODT) ha^{-1} y^{-1}, according to case studies, productivity of willow will increase by 40% till the year 2020 in comparison to 2005, because of the improvement in technologies of soil preparation and development of agro-technical technologies. Yield increase, not always leads to rapid return, it also means increasing harvesting and transportation expenditures (Ericsson et al., 2006). Other reason, which could make plantations more profitable, is rising price of wood chips being the end product of the plantations. Comparing establishment costs of plantations in other European countries, in Latvia fertilization and soil preparation compile only 41.3% of the costs in Scandinavian countries (Ericsson et al., 2009). This and other cost reductions can lead to higher payback rates.

Energy balances of chipped willow can vary from 1:55 to 1:80 (Heller et al., 2004) and the largest energy input use is for harvesting and chipping (30%), storing and drying of the wood (40%) (Danny Harvey, 2010).

Willow is typically planted using 15...20 cm long cuttings. The distance between cuttings is about 0.5 m, distance between rows in double row system is about 0.7 m and between a pair of rows 1.5 m at a planting density of about 12,000...15,000 plants ha^{-1} (Īscirtmeta kārklu plantācijas…, 2011).

The objective of this study was to calculate the economics of growing willow according to the common practice and technology in agriculture land. The calculations were based on model EcoWillow v1.4 (Beta), developed by Buchholz and Volk (Buchholz and Volk, 2011).

Materials and Methods

Willow plantation economical calculations were based on EcoWillow v1.4 (Beta) model, while prices, technologies and growing conditions were based on Latvia's conditions. Economical model is designed from minimum 10 ha planting area. The end product is wood chips with adopted moisture content of 500g kg^{-1}. Transportation of equipment to plantation and transportation of the end product to customer distance is considered to be 50 km. The user can easily enter input data in a spreadsheet, which suits its management model and field, technical and

General data				**Equipment**		
Hectare to be planted	ha	**9**		No. of Units		1
Planter speed	hrs ha^{-1}	1.5		Transport for planter	LVL km^{-1}	0
Total planting time	hrs	14		Transport for tractor	LVL km^{-1}	0
				Distance	km	50
Labour				Total delivery per unit	LVL	0
No. of crews at site		1		Planter rental	LVL hr^{-1} $unit^{-1}$	20
Labourers/crew		2		Tractor rental	LVL hr^{-1} $unit^{-1}$	20
Foreman/crew		1		Tractor fuel consumption	l hr^{-1}	10
Labourer rate	LVL hr^{-1}	3.2		Fuel price	LVL l^{-1}	0.75
Foreman rate	LVL hr^{-1}	5.3		Maintenance	LVL ha^{-1}	5
Hours at site/crew	hrs	14		Hours at site/unit	hrs	14
Indirect labour costs	%	35%		Total	LVL	702
Total	LVL	218		Per ha	LVL ha^{-1}	70
Per ha	LVL ha^{-1}	22				
White cells: insert numbers. Grey cells: output from previous inputs. Bold numbers: connection to other sheets.				**Supplies**		
				Planting stock	LVL $cutting^{-1}$	0.05
				Planting density	cuttings ha^{-1}	13,000
				Stock delivery	LVL	0
				Other supplies	LVL ha^{-1}	5
				Total	LVL	6,026
				Per ha	$ ha^{-1}	603

Figure 1. Planting data input window in EcoWillow economic model.
Source: author's print screen based on EcoWillow model.

financial parameters the best. Calculations are done separately in different windows, according to the activity (see Fig. 1). Activities included in the model are planting, harvesting and transportation. Another field is input data, where it is possible to indicate basic parameters of plantations like project size and project lifespan, internal rate of return (IRR), average biomass increment, rotation length, land costs, incentive payments and biomass price. If necessary, it is possible to include loan payments into calculations. Economical calculations according to plantation life-cycle starts with the establishment costs, which include vegetation removal, herbicide use, ploughing, trenching, installation of fence, weeding in the first and second year and fertilization for a better growth. After the first year cut back is done for faster plant growth.

Establishment costs include planting costs, which are calculated separately. Usually establishment grant or subsidies are given in establishment stage, and if they do exist they are excluded from the costs.

Planting activity is divided in finer parts: general data, labour cost, travel costs and equipment costs. General data variable is planter speed. The labour cost variables are the number of workers, hours worked, hourly rate according to work position and indirect labour costs. Three worker crew works at the planting, as total planting area is assumed to be 9 ha, because 1 ha is for headlands. The hourly rate is estimated according to the average salary in public sector; a foreman hourly rate is calculated according to the average salary in agriculture and forestry sector. Numbers are taken from the CSP database (average salary) and they are similar also in harvesting and transporting fields. Equipment costs include a tractor and planter rent, tractor fuel consumption, fuel price and maintenance. A machine used for planting is an agricultural tractor and transport distance of the equipment is 50 km. Price per cutting and planting density is included in supplies.

A new Holland harvester with a trailer is considered for harvesting, whereas a blower - for loading in transport units. The chips are loaded at a side of the road, directly from field equipment to trucks. Harvesting sub-model includes variables like harvester speed, area to be harvested, biomass to be harvested, row width, length and number, tractor turning and maintenance time as well as tractor speed. Harvesting equipment is represented by a harvester, trailer-tractor and blower rent, fuel consumption and price. Variables for the transport costs of wood chips are bulk density of chips, speed limits on roads, distance, driving time, loading time, dumping time and maximum truck capacity according to the law.

Output data shows net present value (NPV), IRR, average costs, revenues (gross), earning (net)

Table 1

Input/output data for the economic model (EcoWillow Beta v1.4)

Input/output data	Unit	Values
Area	ha	10
Plantation lifespan	Years	22
Rotation length	Years	4
Biomass growth rate	ODT ha^{-1} $year^{-1}$	8
Planting density	cutting ha^{-1}	13,000
Planting stock costs	LVL per cutting	0.05
Biomass price at the gates[a]	LVL ODT^{-1}	33
Land costs	LVL ha^{-1} $year^{-1}$	6
Administration costs	LVL ha^{-1} $year^{-1}$	5
Financial support[b]	LVL ha^{-1} $year^{-1}$	52
Average row length	m	200
Fuel costs[c]	LVL l^{-1}	0.75
Hauling distance	km	50
Truck capacity	t	35
Establishment costs[d]	LVL ha^{-1}	947
Planting costs	LVL ha^{-1}	698
Harvester costs[e]	LVL ha^{-1}	153
Truck costs[e]	LVL km^{-1}	1.7
Planting speed	h ha^{-1}	1.5
Harvester speed	km h^{-1}	6.5

[a] Price in the year 2010
[b] Direct payments are granted directly to farmers under a support scheme - the Single Area Payment Scheme (SAPS)
[c] Fuel price for farmers
[d] Excluding financial support
[e] Including labor, fuel and operation costs

Source: authors survey according to EcoWillow inputs.

for ha and ODT. Calculations show optimistic and pessimistic NPV scenarios. Because of the lack of time and unpredictable circumstances, NPV might fluctuate due to changing costs or revenues. Optimistic scenario predicts 10% increase in revenues and 10% decrease in costs. The pessimistic scenario predicts 10% decrease in revenues and 10% increase in costs.

Results and Discussions

Calculations are done for 22 years plantation lifespan. Soil preparation costs in the beginning before planting are 108 LVL ha^{-1}, establishment costs in the first year excluding the soil preparation in beginning and including incentive payment are 739 LVL ha^{-1}. Establishment and management cost till the first harvest is 794 LVL ha^{-1}. Starting from 2nd year, the annual management costs per year are positive, because of the incentive payment of 52 LVL ha^{-1}. Starting input data are represented in Table 1.

The first commercial harvest of 10 ha costs 1,520 LVL, (33 LVL ODT^{-1}), transport costs 1,642 LVL, yield from all field 294 ODT. IRR over the project 22 year lifespan is 17.1% and NPV is 1,099 LVL. According to optimistic scenario NPV is 1,561 LVL but in pessimistic scenario 638 LVL.

The payback in standard scenario is reached in the 9th year, after the second harvest. According to optimistic scenario, which assumes 10% more revenues and 10% reduction in expenses payback is reached after the first harvest, in pessimistic scenario, which assumes 10% less revenues and 10% more expenses the payback is reached in the 9th year after the second harvest (see Fig. 2).

Over the lifespan of willow plantations, the major part of the costs constitute establishment, harvesting and transporting, 33%, 26% and 29%, Respectively. Other costs like land cost and insurance, administration costs and fertilization together are 12% from all production costs (see Fig. 3).

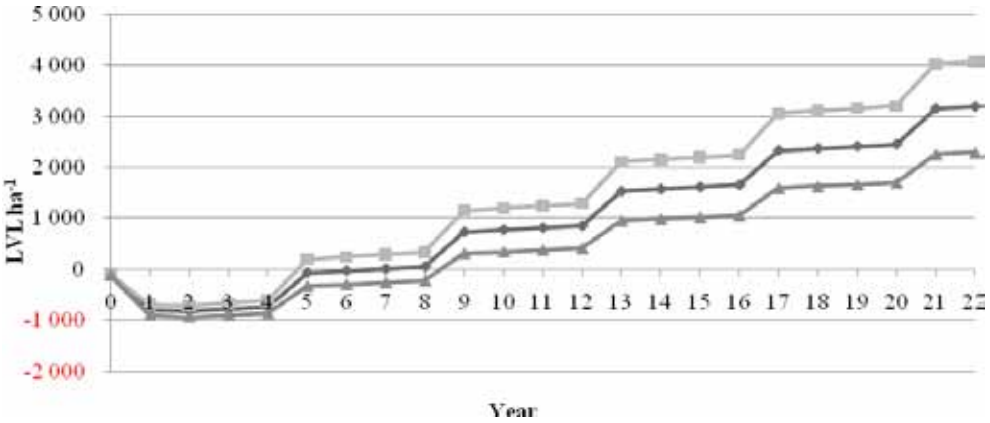

Figure 2. Accumulated cash flow for the project lifetime of 22 years, the payback in standard scenario and pessimistic scenario is in the 9th year after the second harvest, in optimistic scenario the payback is after the first harvest in the 5th year.

Source: author's calculation based on EcoWillow model.

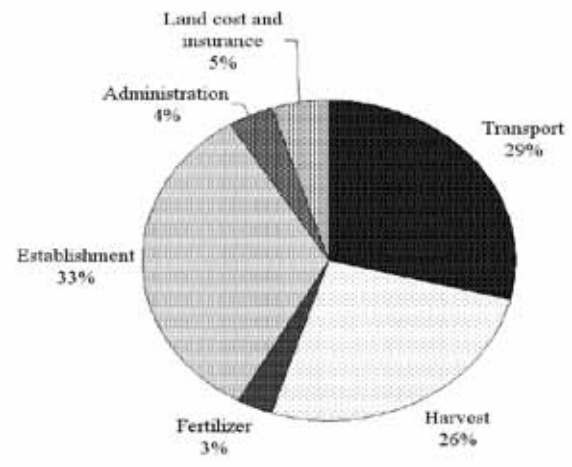

Figure 3. Total production costs of first plantation lifespan.

Source: the author's calculation based on EcoWillow model.

Land rent cost is adapted according to an average of the values for the first two agricultural land base quality classes in the countryside. The average tax rate, using agricultural land from first two quality classes, which is most suitable for willow plantations, is 6 LVL ha^{-1}. If the land costs rise by 50%, that is, up to 12 LVL ha^{-1}, the land cost and taxes will increase to 9% of the total production cost instead of 5 %. In this scenario, the IRR will drop by 11% (from 17.1% to 15.2%), NPV will drop by 8.4% (from 1,099 LVL to 1,006 LVL) and accumulated cash flow will drop by 6.4%. The land tax did not play significant role in economic calculations; even if the tax rises for 50%, it will not significantly affect the total payback time.

To compensate an increase in the land cost tax for 6 LVL ha^{-1} (or 50%, according to the standard scenario), the average biomass increment in a year should rise for 1 ODT ha^{-1} $year^{-1}$ (increase by 12.5%) and achieve 9 ODT $ha^{-1}year^{-1}$, which is average increment of biomass in Southern part of Europe (Ericsson et al., 2009). In the standard scenario the yield (annual increment) is 8 ODT ha^{-1} $year^{-1}$. Increase of the yield by 3 ODT ha^{-1} $year^{-1}$ or 37.5% (to 11 ODT ha^{-1} $year^{-1}$) would increase the IRR by 28.1% (from 17.1% to 21.9%). The harvest costs would increase by 16.4% (from 152 LVL ha^{-1} to 177 LVL ha^{-1}) and transport costs – by 37.8% (from 164 LVL ha^{-1} to 226 LVL ha^{-1}). The total accumulated cash flow would increase by 65.9%. The IRR, harvest and transport cost and accumulated changes of the cash flow compared to the standard scenario are shown in Table 2. To achieve higher yields, it is important to improve breeding, management and technologies in plantation planting and harvesting, (Mola-Yudego, 2011). The lifespan of the plantations in future would be shorter because of the improvement in breeding and technologies. New willow clones are more productive than the older ones and recultivation of old plantations to establish new ones with the new clones would be more profitable than keeping previous plantations for 22 years.

Price of biomass has a great impact on the project payback time. If the price is 13 LVL ODT^{-1} the payback will be reached only after the fourth harvest, at the plantation age of 17 years. The price of biomass did not affect first 4 years of plantation life (see fig. 4), so the assumption of good wood chips price in future could be a reason to establish plantations.

Table 2

Changes in costs according to average yield in willow plantations,%

Average yield in willow plantations, ODT ha^{-1} year^{-1}	Changes of IRR	Changes of harvesting costs	Changes of transportation cost	Accumulated changes of cash flow
8	-	-	-	-
9	+10.5		+12.8	+23.9
10	+20.5		+25.0	+47.9
11	+28.1	+16.4	+37.8	+65.9
12	+36.8		+50.0	+89.8
13	+45.6		+62.8	+113.8
14	+52.0	+32.9	+75.0	+131.8
15	+60.2		+87.8	+155.7
16	+68.4		+100.6	+179.7

Source: authors calculations based on EcoWillow model.

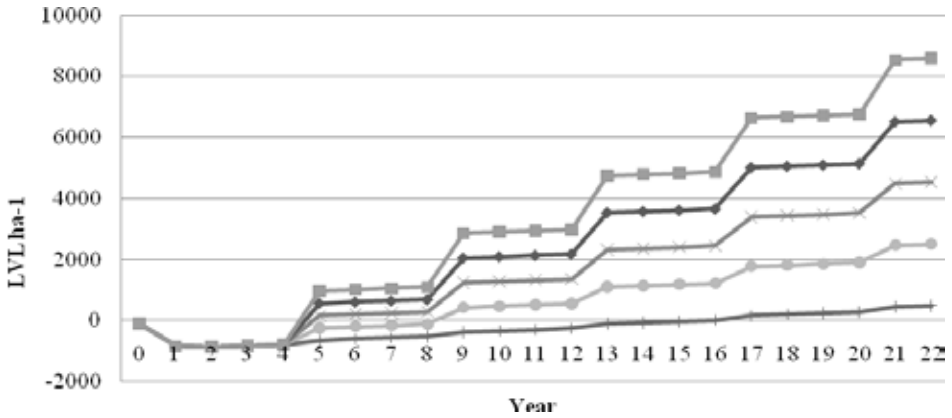

Figure 4. Accumulate cash flow changes of willow plantation, according to biomass price changes, where all other variables are the same.

Source: the author's drawing according to EcoWillow model calculation.

Increase of fuel costs by 0.75 LVL L^{-1} or by 50% (from 0.75 LVL L^{-1} to 1.5 LVL L^{-1}) will raise the planting costs by 1.5% (from 695 LVL ha^{-1} to 705 LVL ha^{-1}), the harvesting costs will increase by 30.9% (from 152 LVL ha^{-1} to 199 LVL ha^{-1}) and transporting costs – by 29.2% (from 164 LVL ha^{-1} to 212 LVL ha^{-1}). The fuel costs plays a significant role in harvesting and transportation; similarly, other costs like cutting price, ploughing and trailer costs will rise, because of the use of fuel in all of these activities.

In some cases financial support in establishment stage is an important factor to make a choice in favour of willow plantations instead of not using the abandoned agricultural land. The first earnings are possible only after the first harvest; therefore, a single establishment grant for the willow plantation would make them more attractive to farmers and move the payback to the first harvest. The establishment grant should be 50% of the establishment costs to make positive cash flow after the first harvest. In the standard scenario if the establishment grant is 400 LVL ha^{-1}, the payback is reached after the first harvest and the IRR will increase by 62% (from 17.1% to 27.7%).

Conclusions

The costs of willow plantation include positions from different sectors (plantation establishment, harvesting and transport). Increase or decrease of the costs in a particular sector leads to changes in the plantation cash flow during plantation lifespan. Standard model for plantation of 10 ha area and lifespan 22 years is provided in the study. In standard scenario IRR is 17.1%, NPV is 1,099 LVL and the payback is reached in the 9th year or after the second harvesting. The establishment costs in the first year are 739 LVL ha^{-1}; harvesting costs in the first harvest are 152 LVL ha^{-1} and transport costs of wood chip are 164 LVL ha^{-1}. Major part of the costs is establishment (33%), harvesting (26%) and transportation (29%); all remaining costs taken together constitute 12% of the total production costs. If the costs of land rise by 50% (to 12 LVL ha^{-1}) the land cost and taxes in

total production costs will rise to 9%, IRR will drop by 11%, NPV will drop by 8.4% and accumulated cash flow will drop by 6.4%. Increase of the yield by 3 ODT ha^{-1} $year^{-1}$ or 37.5% (to 11 ODT ha^{-1}) will raise the IRR by 28%, harvest costs - by 16.4% and transport costs by 37.8%. The most important role in economics of plantation plays price of wood chip and fuel. The land tax did not play a significant role in economic calculations; even if the tax rises for 50%, it will not significantly affect the total payback time. One of the best solutions to make establishment of willow plantation more attractive to farmers, is an establishment grant. If the establishment grant is 50% from the establishment costs, the payback in the standard scenario can be reached after the first harvest.

Acknowledgements

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References

1. Buchholz T., Volk A.T. (2011) Improving the Profitability of Willow Crops – Identifying Opportunities with a Crop Budget Model. *Bioenergy Research*, 4, pp. 85–95.
2. Danny Harvey L.D. (2010) Energy and the New Reality 2 Carbon-Free Energy Supply. Biomass energy. In: Routledge, Earthscan LLC, 1616 P Street, NW, Washington, DC 20036, USA. pp. 173–279.
3. Directive 2009/28/EC. On the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC. (2009) pp. 16–62.
4. Ericsson K., Rosenqvist H., Nilsson L.J. (2009) Energy crop production costs in the EU. *Biomass and Bioenergy,* 33, pp. 1577–1586.
5. Ericsson K., Rosenqvist H., Ganko E., Pisarek M., Nilsson L. (2006) An agro-economics analysis of willow cultivation in Poland. *Biomass and Bioenergy*, 30, pp. 16–27.
6. European Biomass Association (2011) 2011 Annual Statistical Report on the Contribution of Biomass to the Energy System in the EU27. AEBIOM, Brussels. pp. 1–30.
7. Gonzalez-Garcia S., Bacenetti J., Murphy J.R., Fiala M. (2012) Present and future environmental impact of poplar cultivation in the Po Valley (Italy) under different crop management systems. *Journal of Cleaner Production,* 26, pp. 56–66.
8. Hall D.O., House J.I. (1994) Tress and biomass energy: carbon storage and/or fossil substitution? *Biomass and Bioenergy*, 6, pp. 11–30.
9. Heller M.C., Keoleian G.A., Mann M.K., Volk T.A. (2004) Life cycle energy and environmental benefits of generating electricity from willow biomass. *Renewable Energy*, 29(7), pp. 1023–1042.
10. Jossart J.M. (2006) Boosting bioenergy in Europe, AEBIUM, Belgium Available at: www.aebiom.org., 25 April 2012.
11. Latvian Energy in Figures. Ministry of Economics of the Republic of Latvia. (2011) Riga pp. 27.
12. Lazdina D. (2009) Notekūdeņu dūņu izmantošanas iespējas kārklu plantācijās (Usage of Sewage Sludge in Willow Plantations) Promocijas darba kopsavilkums Dr. silv. zinātniskā grāda iegūšanai mežzinātnes nozarē, meža ekoloģijas un mežkopības apakšnozarē. Jelgava. 58. lpp. (in Latvian).
13. Lazdiņa D., Lazdiņš A. (2011) Īscirtmeta kārklu plantācijas un to izmantošanas iespējas (Short- term Willow Plantation Use Possibilities). LVMI 'Silava' 36. lpp. (in Latvian).
14. Lazdins A. (2011) Dabiski apmežojušos lauksaimniecības zemju efektīvas apsaimniekošanas nosacījumi. (Conditions on Naturally Forested Agricultural Land Effective Management). Promocijas darba kopsavilkums Dr. silv zinātniskā grāda iegūšanai mežzinātnes nozarē, meža ekoloģijas un mežkopības apakšnozarē. Jelgava, 50. lpp. (in Latvian).
15. Mola-Yudego B. (2011) Trends and productivity improvement from commercial willow plantations in Sweden during the period 1986-2000. *Biomass and Bioenergy*. 35. pp. 446–453.

POLICIES RELATED TO VOLUNTEER WORK IN LATVIA

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Abstract
Volunteer work has been identified as a relatively new kind of leisure activities. It plays an important role in various, at the same time it is a great possibility to learn, acquire new skills and accumulate human capital while taking part in volunteer activities. Therefore, the objective of the study is to research the policies related to voluntary work and their relevance in realization and development of volunteer work in Latvia. Theoretical literature shows that in Latvia the volunteer work is mentioned in some policies – economic, youth policies and civil society. In the framework of economic policy successful development of volunteering enhances the progress of economic processes in the state in two ways by making contributions to Gross Domestic Product; by accumulating person's human capital, results illustrate that although the term "voluntary work" has a long history, infrastructure for realisation of the voluntary work has not been developed in Latvia, and regulatory enactments do not cover voluntary work in an adequate manner. After the analysis the author believes that volunteering is widely discussed in the youth policy as there is law and a range of structured documents where aspects of volunteer work are mentioned. According to the results of research, in the frame of civil society it must be noted that in Latvia the voluntary work movement has to be examined in the context of the establishment of non-governmental organizations because voluntary work movement started to develop in a purposeful and organized manner only in 1998 in non-governmental organizations.
Key words: volunteer work, economic policy, youth policy, civil society.

Introduction

The aim of economic policy is to ensure sustainable and balanced economic and social development, to implement transition from labor-intensive economy to a knowledge-based economy, where human capital is one of the key factors that define the potential of a country's economic growth. Increase of productivity is treated as a result of accumulation of knowledge. Volunteering could be used as a tool to accumulate human capital in person's free time. Therefore, topicality of the research is volunteer work as a concept of spending leisure time purposefully. The author of this study has created the definition of voluntary work as follows: **voluntary work is unremunerated activities that are carried out of one's own free will, in one's free time under organized conditions, thus promoting personal, social and economic well-being**. As regards the analysis made in the research, it is clear that no infrastructure (no legal framework, no data systematically gathered on volunteering, no organisation regularly analysing data on volunteering etc.) currently has been created for realization and development of the volunteer work in Latvia. At the same time theoretical literature shows that in Latvia the volunteer work is mentioned in aspects of civil society and youth. In respect of this, the objective of the study is to research the policies related to voluntary work and their relevance in realization and development of volunteer work in Latvia.

The following tasks are advanced to achieve the objective:

1. To develop a definition of voluntary work;
2. To research development of voluntary work in different policies in Latvia;
3. To show the relevance of voluntary work and its role in the development of human capital;

To achieve the objective, the following research methods were used: a monograph method, comparative method, constructive logics, analysis and synthesis, inductive and deductive methods.

Results and Discussion

Schematic description of the links between volunteering and other applicable aspects are shown in figure 1. Further the analysis of volunteering in economic, youth policies and civil society are shown in the text.

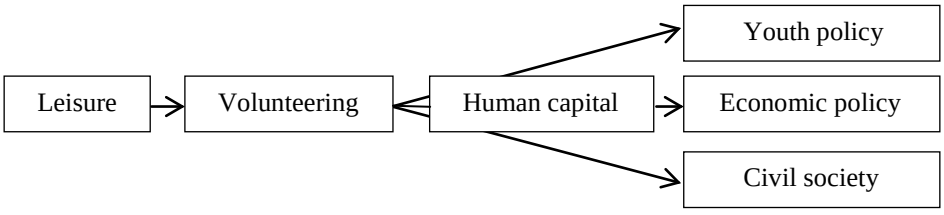

Figure1. Links between volunteering and policies.
Source: Author's construction based on the literature analysis.

Voluntary Work in Economic Policy

An aim of economic policy is to ensure sustainable and balanced economic and social development, to implement transition from labor-intensive economy to a knowledge-based economy, where human capital is one of the key factors defining the potential of the country's economic growth. With the restoration of independence in the early 90's Latvian government moved quickly to restore a free market economy, encourage privatisation, stabilise the currency and diversify import and export flow. As a result, Latvia rapidly emerged as one of the economic success stories of the post-Cold War period. Although Latvia suffered an economic downturn during the global economic crisis, there are encouraging indications of a recovery. After stabilisation of economic situation, growth should follow. Human capital – knowledge, skills, abilities and other characteristics that promotes personal, social and economic welfare – is one of the key factors defining the potential of the country's economic growth. As defined by the objective of the Latvian National Development Plan 2007-2013, an educated and creative person is a priority for improving the quality of life. By undertaking voluntary activities in his or her free time, an individual can accumulate his or her human capital, which provides a link between voluntary work and economic processes. Therefore, successful development of volunteering enhances the development of socio-economic processes in the state.

In Latvia economic recession, started from 2008, severely affected the labour market. In past years unemployment rate in Latvia was low, the ratio of jobseekers exceeded 20% of the economically active population at the end of 2009. The main challenges for the labour market were to enhance labour competitiveness. In order to implement this target, two types of measures were made – short-term measures, aimed at alleviating the severe social consequences of the crisis and long-term measures, aimed at enhancing the labour force competitiveness. One of the short-term crisis measures is connected with volunteering. It is 'Support for youth volunteer work'. Measure is planned with the aim to support activities of young unemployed aged 18-24 years, promoting opportunities and developing the volunteer work in Latvia, taking into account youth potential and current situation in the labour market. The participants will work in associations and foundations (up to 6 months) receiving monthly allowance of 57 EUR and 85 EUR for young unemployed with special needs (Latvian…, 2011). This measure is stressed also in National Reform Programme of Latvia for the Implementation of the "Europe 2020" strategy where as the key policy directions and measures for decreasing the risk of structural unemployment is demonstrated activity: "Improving active labour market policy measures by gradual transition from crisis-related measures to traditional active labour market policy measures". The aim of this activity is to carry out active labour market policy measures reforms to increase their efficiency and quality of the unemployed training process (2011–2013). As one of the tools to reach this aim is a plan to introduce new measures targeted at young unemployed for a practical work trial and for voluntary work. (National…., 2011)

After reviewing literature, it can be concluded that the current legal order pertaining to voluntary work is insufficient. At the moment the legal framework for volunteer work activities is provided by the Associations and Foundations Law and the Youth Law. It is insufficient because it is very important to define a wider spectrum of legal subjects that can employ volunteers, because the current regulatory enactments generally regulate only voluntary work by young people (people who are 13 to 25 years old) and voluntary work in associations and foundations, but do not regulate the procedures specifying how other legal subjects - public institutions, local authorities, political parties and religious organizations - employ volunteers who are not young people.

Interestingly, in 2005, a draft law called the Law on Volunteer Activities was formulated to address these faults. It was hoped that the draft law would provide basic definitions for ensuring and implementing volunteer activities in Latvia. It was also planned for the draft law to prescribe the rights and duties of both the volunteer and volunteer organization. The draft law was declined, due to the conclusion that there is a need to reconsider the legal order envisaged in it and to address the declarative nature of the draft law (Strode, 2008).

After the draft law failed to be put in effect, the issue of organizing the legal framework governing voluntary work has become topical in the context of the implementation of the planning period 2007–2013 of the European Union Structural Funds and the Cohesion Fund. The Informative Report on Proposals for the Simplification of European Union Funds Acquisition prepared by the Ministry of Finance was examined by the Cabinet in September 2009, which is indicative that this issue has become topical. While examining the Report, the Cabinet delegated the task of amending regulatory enactments by defining the concept of voluntary work as well as by setting the principles for registering voluntary work in accounting.

On 5 October 2010, the Cabinet examined the draft law Amendment to the Civil Law. In accordance with the amendment, it is planned to add Sub-Chapter 5 'Contracts for Volunteer's Work' to the Civil Law, Chapter 15 'Claims Arising from Employment Relations'. Sub-Chapter 5 is planned to prescribe

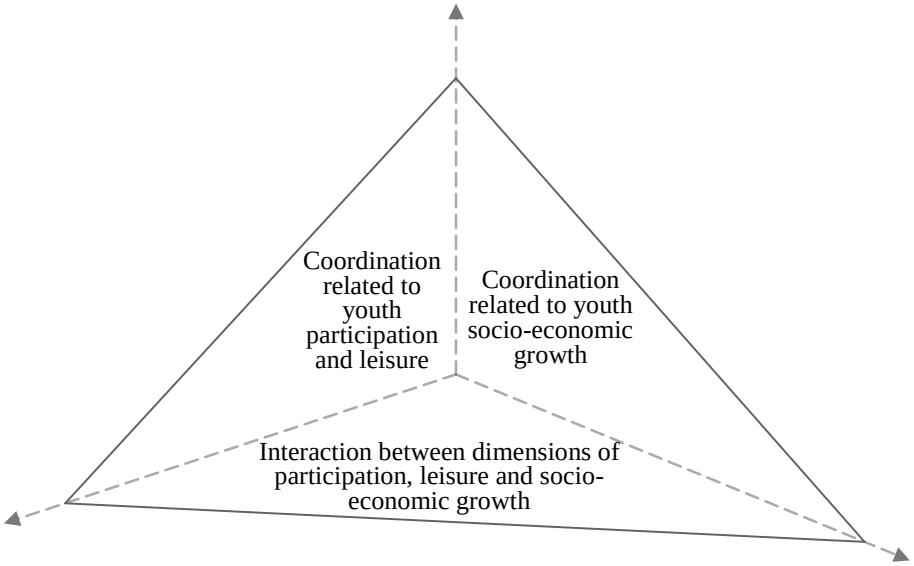

Figure 2. Dimensions of Youth Policy.
Source: Youth policies guidelines 2009–2018.

that with a contract for volunteer's work one party - the volunteer - shall undertake to carry out such tasks set by the other party - organizer of voluntary work - without remuneration that correspond to an objective that does not involve material benefits and that is prescribed in the organizer's by-law, articles of association or constitution (Luse, 2010). However, the amendment does not stipulate all of the tasks mentioned above delegated by the Cabinet in 2009; it does not define voluntary work, and it does not ensure the use of voluntary work for a wider spectrum of legal subjects, because it might not give a businessman the right to use voluntary work, because the purpose of the businessman's business is to gain profits. Thus, it is currently controversial whether, in accordance with the planned amendment, the purpose of the organizer of voluntary work always has to be other than gaining profits, or whether the purpose has to be other than gaining profits only in cases where there is a wish to use voluntary work. Although at the moment it is impossible to forecast when the Saeima might approve the amendment, after the amendment has come into effect, the practical application of the law will prove the effectiveness of the amendment in the development of voluntary work (Berlaus, 2010).

Voluntary Work in Youth Policy

After carrying out the analysis, the author believes that volunteering is widely discussed in the youth policy. This is demonstrated not only by existing law and by the range of structured documents, but also by included aspects of volunteering as well. Youth policy aspect of volunteer work is related to a context of a useful free time spending. This is proved by Figure 2, which includes information that, in accordance with Youth policies guidelines of the year 2009 till 2018, the youth policy in Latvia consists of three dimensions, of which one is promotion of young people's participation and appropriate leisure time usage. Within these guidelines, volunteering is seen as one of the ways young people can spend leisure time usefully.

Leisure aspect has already been discussed within youth policy in National Youth Policy Program in the year 2002. The improvement of youth's useful leisure time organization is being promoted as one of the programs' priorities. According to the activities that have been set out in reaching programs' objectives and targets in 2002, volunteering does not appear as a leisure form of organization yet, but actual are for example such measures as projects competition organizing, providing development of the children and youth in educational camps with certified programs, organizing annual competition for talented young people, vocational training to support music and the arts.

Voluntary work in its actuality appears in National Youth Policy Program for the year 2005 till 2009, where a youth non-formal education system, developed youth volunteering and increased opportunity for young people to use their leisure time purposefully has been mentioned as one of the program's policy results. Within the program, volunteering is understood as a donation of time and skills for public purposes, which allows using leisure time appropriately, building self-confidence and also allows to utilize existing skills and gain new ones, that can serve as a source of work experience. Thus, the author believes that within this program voluntary work is being updated not only from a point of discussion of the term, but also

because there are offered such a kind of indicators that gives an opportunity to judge the results. The fruitful qualitative criteria include issues relevant to this day, that is, examples include the following criteria: the willful use of volunteer opportunities in Latvia, encouraged young people into voluntary work activities, managed instruction of the youth advisors. There has also been raised a quantitative criterion, which determines that the number of youth taking part in voluntary activities should increase. At this moment an important issue is a mechanism used to monitor an accomplishment of the criterion, as, for example, volunteers registration still does not occur in Latvia.

From the author's view the criteria reaching monitoring is important issue according to the approved documents on the youth policy, which primarily are a Youth Policy guidelines for the year 2009–2018. These guidelines provide a displayed volunteer work situation, and there are financial, administrative and organizational obstacles to volunteer work as well as problems, which can be avoidable by realizing these guidelines mentioned. Also, fruitful indicators such as proportion of young people (%), who have done volunteer work at least once, reduced proportion of young people, who say, that they will never work without wage are being discussed. The author considers, that the criteria will not reflect the reality of young people's involvement in the implementation of voluntary work, since, as mentioned above, voluntary register is not maintained at the national level. Therefore, it is possible to use a questionnaire method for monitoring indicators, which is not representative, if the indicators are monitored long term, providing regular information on changes of the situation.

Based on specified guidelines in the paragraph above, the country has developed National Youth Policy program for 2009–2013, which is a medium-term planning document for the next 5 years with the aim to provide guidelines for implementation of this document during the period from 2009 to 2013. Regarding voluntary work, the program sets the results to be achieved in the development of youth's voluntary work in the following examples: preparing informational materials for young people about volunteering, organizing awareness campaigns in educational institutions on volunteering, promote volunteering during student project weeks. Based on number of results, the author believes, that the parameters defined for the volunteer recognition of acquired skills are worth mentioning, because it is an essential aspect in this case for the development of youth volunteering.

In the Youth Policy documents hierarchical subordination, the annual program designed for one year and in accordance with the program taking into account the EU Presidency's priorities in youth policy is also included. For example, the National Youth Policy Program for the year 2011, the voluntary aspect is incorporated according to the European Parliament's resolutions on 22nd of April in 2008 on the importance of volunteering to economic and social (2007/2149 (INI) 19. point advised to declare the year 2011 as a volunteer year. Consequently, the year 2011 program also includes the mandatory tasks, such as the implementation of the European Year of Volunteering 2011 program, including organizing the European Year of Volunteering promotional activities.

Voluntary Work in Civil Society

Unlike the long-term traditions concerning the development of voluntary work in the world, it must be noted that in Latvia, voluntary work movement started developing in a purposeful and organized manner only in 1998. In Latvia, the voluntary work movement has to be examined in the light of the establishment of non-governmental organizations. Although the oldest associations and organizations in Latvia were established in the feudal period as trade fraternities and guilds founded by German conquerors, associations were founded on a wider scale in the second half of the 18th century and in the first half of the 19th century. Those were scientific, charitable and mutual help associations of a practical nature (Skubina, 2001). During the First World War, the activities of the associations dwindled, but after the battles for Latvia independence, the bustle of social life started anew, this time in an independent country. A number of associations founded before the First World War re-started their work, and new ones were founded. The activities of associations were regulated by the Law on Associations, Unions and Political Organizations, issued in 1923. The Law stipulated provisions that had to be complied with when founding an association. The provisions envisaged that in order to found an association, one had to submit articles of association, names of the founders, the composition of the administrative bodies, procedures for election, information regarding the existence of funding, and other information. Interestingly, the Law stipulated that one could become a member of an association starting from the age of 18. As the provisions mentioned above can be assessed as simple requirements, they promoted a rapid increase in the number of associations. In 1928, 8,035 associations were registered in Latvia (Indriksons, 2009).

After the Soviet occupation, the associations were abolished or re-organized, thus providing opportunities to spread propaganda and execute the decisions made by the Communist party. When the transition to democracy took place, the structure, type of activities and role in the society of non-governmental organizations changed, and they served

as the basis that civic society formed on. As has been mentioned before, voluntary work also developed in a democratic Latvia in a purposeful and organized manner, as it is demonstrated by the fact that in 1998 a programme with support from the Soros Fund to develop voluntary activities in Eastern Europe (Skubina, 2001) was established.

Volunteering is also included in Strengthening Civil Society Program for the year 2008 to 2012. It argues that voluntary work, as well as the donation, is important indicators characterizing the public. The stronger is the tradition of civil society, the more people donate not only money but also their time, skills, knowledge and other skills through volunteering. Accordingly, such actions as rewarding the volunteers (most active volunteer organizations and NGOs rewarding), continued support for the providers of voluntary activities and the voluntary regulatory arrangement, whose progress has been analyzed in the previous section of the work are being organized.

Although the program's date is the year 2012, however, in 2010 the Ministry of Justice led to the harmonization of social integration policies of the draft guidelines, where the volunteer work was not emphasized as an element of society to facilitate integration. However, as in Latvia a number of institutional reforms affecting all the state institutions, including institutions that deal with integration issues in Latvia are carried out, then with the Ministry of Culture of social integration transfer function from the Ministry of Justice on December 7, 2010, national identity and social integration policies guidelines for 2012th – 2018th year were prepared. Although on the 3rd quarter of 2011, these guidelines still appear as a further public consultation project, however, these guidelines are reflected in volunteering as a new form of participation, which characterizes civic activities in Latvia with non-governmental organizations. Therefore, integration policy is set in a new role - not only promoting the traditional civic participation but also strengthening the sustainability of the new form of participation. Positively, these guidelines are highlighted in the source of funding - the European Economic Area and Norwegian Financial Mechanism - with the support to pursue its mission - to develop the civic participation of traditional and non-traditional forms, including volunteering in all age groups. The binding indicator is set in percentage of population that gets involved in voluntary work (%), whereas the base value the market and public opinion research center SKDS 2007 study "The most urgent aspects of social integration" results, the rate of 24.3 set % in value is used. The value to reach in 2018 is 30%, and intermediate value in 2004 was 27%. Regarding this, a previously mentioned problematic aspect of no data on the voluntary movement stored at national level should be focused on; thus, it is quite hard to obtain accurate data in the following years, so that it possible to compare them to the baseline value.

Conclusions

1. Voluntary work definition should include all important aspects of volunteering – work for free, in leisure time, promoting well-being. All aspects mentioned before are included in the definition of volunteer work.
2. Current regulatory enactments in effect in Latvia stipulate putting into effect voluntary work merely within a specific field.
3. Volunteering work is not appropriately referred to in a very important policy – economic policy.
4. During voluntary activities in his or her free time, an individual can accumulate his or her human capital, which is one of the key factors defining the potential of the country's economic growth.
5. In Latvia the volunteer work is mentioned in aspects of civil society and youth.
6. The data of voluntary movement is not stored at national level; therefore, the baseline value and annual value of indicators couldn't be defined for development of volunteering in Latvia.

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References

1. Berlaus E. (2010) Brīvprātīgais un „brīvprātīgais" darbs (Volunteer and "Volunteer" Work). Available at: http://db.lv/r/354-blogi-viedokli/355-blogi/367-eva-berlaus/233337-brivpratigais-un-brivpratigais-darbs, 29 December 2010 (in Latvian).
2. Dovladbekova I. (2005) Cilvēkkapitāla attīstība kā Latvijas ekonomiskās konkurētspējas paaugstināšanas faktors. (Development of human capital as the factor for increasing the competitiveness of Latvian economy). Latvijas Zinātniskās padomes Ekonomikas un Juridiskās zinātnes galvenie pētījuma virzieni Nr. 11. Riga, 36. lpp. (in Latvian).
3. Indriksons M. (2009) Vēsturiskas ziņas par nevalstisko organizāciju darbību Talsu novadā. (History of NGOs in Talsu district). Available at: www.zkcentrs.lv/informatvie-dokumenti/9-dokumenti/35-nvo-vesture, 15 November 2010 (in Latvian).

4. Jaunatnes likums (Youth Law) (2008) Available at: http://www.likumi.lv/doc.php?id=175920, 1 January 2011 (in Latvian).
5. Jaunatnes politikas pamatnostādnes 2009. – 2018.gadam (Youth policy guidelines 2009 - 2018) (2009) Available at: http://izm.izm.gov.lv/upload_file/Normativie_akti/IZMpamn_021009.pdf, 18 August 2011 (in Latvian).
6. Jaunatnes politikas valsts programma 2005 – 2009. gadam (National Youth Policy Program 2005-2009) (2005) Available at: http://www.likumi.lv/doc.php?id=107520&from=off, 18 August 2011 (in Latvian).
7. Jaunatnes politikas valsts programma 2009 – 2013. gadam (National Youth Policy Program 2009-2013) (2009) Available at: http://www.likumi.lv/doc.php?id=196801, 18 August 2011 (in Latvian).
8. Jaunatnes politikas valsts programma 2011. gadam (National Youth Policy Program 2011) (2011) Available at: http://www.likumi.lv/doc.php?id=196801, 18 August 2011 (in Latvian).
9. Latvijas ilgtspējīgas attīstības stratēģija 2030. gadam (Latvia's Sustainable Development Strategy 2030) (2010) Available at: http://www.latvija2030.lv, 20 April 2010 (in Latvian).
10. Latvian Labour Market 2010-2011. (2010) Available at: http://www.lm.gov.lv/upload/darbs_eng/labour_market_10_11.pdf, 18 February 2012.
11. Likumprojekts „Brīvprātīgo darbības likums" (Draft law „Law on Volunteer Activities") (2005) Available at: http://www.politika.lv/index.php?id=5809, 13 July 2009 (in Latvian).
12. Likumprojekts „Grozījums Civillikumā" (Draft law Amendment to the Civil Law) (2010) Available at: http://www.mk.gov.lv/lv/mk/tap/?pid=40182814, 4 January 2011 (in Latvian).
13. Likums „Biedrību un nodibinājumu likums" (Associations and Foundations Law) (2004) Available at: http://www.likumi.lv/doc.php?id=81050, 20 April 2010 (in Latvian).
14. Luse L. (2010) Ar grozījumiem Civillikumā regulēs brīvprātīgo darbu (Volunteer work will be regulated by Amendment to the Civil Law). Available at: http://lv.lv/?menu=doc&id=213468, 29 December 2010 (in Latvian).
15. National Reform Programme of Latvia for the Implementation of the "Europe 2020" strategy (2011) Available at: http://ec.europa.eu/europe2020/pdf/nrp/nrp_latvia_en.pdf, 29 July 2012.
16. Skubina V. (2001) *Brīvprātīgie sociālajā darbā: mācību metodiskais līdzeklis* (Volunteers in Social Work: Study Guide). Riga: Sociala darba un socialas pedagogijas augstskola „Attistiba", 114. lpp. (in Latvian).
17. Strode L. (2008) *Kas regulē brīvprātīgo darbu?* (What regulates volunteering?). Muzeju Valsts Parvaldes Specializdevums, 20. lpp. (in Latvian).
18. Valsts jaunatnes politikas koncepcija (2002) (National Youth Policy Concept). Available at: http://www.jaunatneslietas.lv/page/1234, 20 August 2011 (in Latvian).

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AN EVALUATION OF USING FUEL WOOD FOR DISTRICT HEATING PRODUCTION IN LATVIA

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Abstract
One can reasonably argue that issues related to the increased use of renewable energy resources in the energy production processes in Latvia, are at the forefront and will remain there in the future. This relates to the aspect that Latvia is not rich in non-renewable energy resources (around 70% of total primary energy consumption in Latvia is ensured by import, which can lead to undesired effects in many areas), but at the same time, there are available renewable energy resources in Latvia, with an untapped potential to be recognized. In particular this applies to fuel wood, which is already (year 2012) the most important domestic fuel in Latvia. In this context it is important to emphasize that, according to the particular study results, if unexpected socio-economic developments do not take place, raw wood material resources required for different types of fuel wood production in Latvia should be available in the same amount as it is now if not more. As for increasing the amount of fuel wood use in Latvia, an enormous 'potential' can be seen in general use boiler houses, where there are currently no technological limitations to utilize this 'potential'. General use cogeneration plants can be recognized as an even greater 'potential' for greater use of fuel wood in Latvia, but given the circumstances of energy supply in Latvia, the 'potential' is currently available on a very limited basis. At the same time it is important to note that both of these 'potentials' could be significantly reduced in the next few years.
Key words: fuel wood, district heating, power sector.

Introduction

By studying the current situation regarding the use of the energy resources in Latvia, the focus should be on two major issues. First, the power sector of Latvia is characterized by a relatively high dependence on the supplied energy resource import. For example, in 2010 the total primary energy consumption was 200.55 PJ (peta-joules) and only 33.21% (66.58 PJ) of it was provided by local energy resources, including a 32.79% share produced from utilizing renewable energy resources (hereinafter – RES). In these circumstances, Latvia may be subject to political, commercial and legal uncertainty, associated with the supply of imported energy resources and price. In addition, there is an outflow of funds from Latvia, due to payments for the imported energy resources, which results in contributing to the economic development of another country. Second, geographically Latvia is located in northern Europe, where thermal energy is needed not only to improve the quality of life, but also serves as a prerequisite for survival during winter. If we compare three main sectors, where the society utilizes energy, it is noticeable, that the largest portion of specific energy consumption in Latvia is for heating, but the least – for electricity, whereas transportation occupies the middle position. Therefore, heating is a particularly important power sector in Latvia. An additional nuance, which must be pointed out, is that the main RES sources in Latvia are agriculture and forestry, which are scattered throughout the country. The solid biomass obtained from these sources is suitable for the production of heat using widely tested technologies brought to the market, in contrast to the so-called production technologies of 'green' electricity (produced by the use of RES), Latvia is largely able to provide it by itself (Siltumapgāde Latvijā, 2009; Klāvs et al., 2010).

By understanding the importance of the aspects and cross-correlations mentioned above, it is possible to come to a conclusion, that the approach including heat production from agricultural and forestry biomass in Latvia, by looking at the situation in general, is already becoming stressed as a significant opportunity to promote the national economy and regional economic development, as well as new energy technology and product development, and also increase the independence of Latvian power sector. This clearly defines the actuality of the research topic.

In this particular study an assessment of using fuel wood of district heating in Latvia is selected as the ***research object***. The study is delimited by the ***research subject***, which anticipates the use of fuel wood in general use boiler houses and cogeneration plants.

Research aim: Evaluate the use of fuel wood for district heating in general use boiler houses and cogeneration plants in Latvia.

Research tasks:

1. to describe wood resources in Latvia.
2. to analyse the actual and perspective use of fuel wood for district heating in general use boiler houses and cogeneration plants in Latvia. In this particular study the words 'fuel wood consumption in perspective' are meant as an amount of fuel wood, which, due to a variety of circumstances, has in fact already been scheduled for energy production in the foreseeable future, by taking real actions, which ensure the predicted amount of fuel wood use.

Materials and Methods

The study is developed in the year 2012. To describe the object under study the monographic method is used frequently for both overall and between object parts, analysis and synthesis methods are also applied. The main source of information of the study is the publicly available database of the Central Statistics Bureau (hereinafter – CSB) of Latvian Republic (hereinafter – LR), as well as the forest inventory data of the State Forest Service (hereinafter – SFS). Similarly the study includes analytical information, acquired from research analysis carried out by academic and scientific staff (professional researchers), as well as some Internet sources.

Results and Discussion

1. Characteristics of Latvian wood resources

Forests in Latvia are clearly the national treasure. Based on the SFS (a public administration under the supervision of LR Ministry of Agriculture) forest inventory data for 2010, the total area of the forest land was 3264.64 thsd. ha (thousand hectares). By comparing this area to the total land area of Latvia (6459.8 thsd. ha), it is possible to attain a result, that in 2010 forest cover in Latvia was 50.5% (in comparison with the national average most of the forests in Latvia are located in the regions of Kurzeme and Vidzeme). By growing the trees form wood increment each year. The current estimates of SFS for recent years show that, at the moment it is about 16.5 mln. m^3 (million cubic meters) per year in Latvia. At the same time each year a certain amount of wood is felled (see Tab. 1). By associating these two figures together, a situation becomes distinct, where the total volume of forest growing stock in Latvian forests has increased, as forest growth is greater than the volume felled. In essence, this means, that the existing volume of tree felling in Latvia until now corresponds to the principles of sustainable forest management (Meža apsaimniekošana, 2012).

Table 1

Total forest growing stock and volume felled (million cubic meters) in Latvia from 2005 to 2010

Position	Report year, million cubic meters					
	2005	2006	2007	2008	2009	2010
Total forest growing stock	569	571	569	569	571	576
Volume felled in total*	11.29	9.81	10.12	8.96	10.73	12.98
state forests	4.80	4.41	4.69	5.54	7.73	7.64
other forests	6.49	5.40	5.43	3.42	3.00	5.34

* Volume felled, where it has been necessary for the SFS to issue a tree felling confirmation.
Source: made by the authors on the basis of SFS data.

Table 2

The distribution of the total dominant tree species growing stock (million cubic meters) and the total area (thousand hectares) in age classes in all Latvian forest for the year 2010

Age class, years	Total growing stock, million cubic meters			Total area, thousand hectares		
	Pine	Spruce	Birch	Pine	Spruce	Birch
to 10	0.68	1.13	1.66	50.48	80.71	80.25
from 11 to 20	1.14	2.05	4.23	39.70	54.94	87.60
from 21 to 30	1.38	5.75	4.18	20.91	63.13	43.60
from 31 to 40	3.55	11.95	7.65	26.95	74.49	53.20
from 41 to 50	7.44	17.33	16.62	40.47	74.25	89.84
from 51 to 60	17.63	7.91	33.01	76.99	28.94	147.52
from 61 to 70	32.82	7.97	41.81	126.35	26.36	165.51
from 71 to 80	38.14	9.02	24.33	139.78	27.80	93.09
from 81 to 90	38.51	9.03	13.56	134.01	27.46	51.09
from 91 to 100	34.37	8.20	8.65	115.97	25.26	31.86
from 101 to 110	25.73	5.19	3.64	84.77	15.88	13.46
from 111 to 120	15.45	2.74	1.01	51.61	8.54	3.91
over 120	30.16	3.34	0.31	105.29	11.02	1.29

Source: made by the authors on the basis of SFS data.

While analyzing the information on the total forest growing stock in Latvia (see Tab. 1), it is imperative to be aware that it marks a situation with wood resources in the country as a whole, but does not provide an insight in the actual availability of potential resources, because logging activities are planned, depending on tree species composition and the distribution of growing stock in age classes. By taking this into account, a summary of the most common Latvian tree species and their growing stock and area distribution in age classes was made (see Tab. 2). Latvian forest stands mainly consist of three dominant tree species: pine, spruce and birch. In accordance with information available on the LR CSB database, pine, spruce and birch forest stands together form 74% of total forest area in Latvia.

In order to assess the information, provided by Table 2, in detail, there is a further need to identify the distribution of dominant tree species by the site index. Site index is a man-made classification unit for the description of the productivity of a forest stand, which is determined on the basis of tree height at a certain age. To put it in simple terms, the site index indicates the rotation age (see Tab. 3) of the dominant tree species to be felled in the final felling. According to the information of LR Ministry of Agriculture, spruce and birch mostly make up I and II forest stand site index in Latvia, while pines generally constitute I, II and III forest stand site index (Meža platība, 2010).

By taking into consideration the contents of Table 2 and 3, it is clear that the accumulation of grown and overgrown pine forest stands has taken place in Latvia. There has also been the accumulation of spruce and birch forest stands, though not in quantities as large as pine forest stands. In addition, with the exception of spruce stands, where forest stands being in the minority will have reached the existing final felling age within the next 30 years, in birch and pine stands the majority of the forest stands is where the final felling age will be reached in 10 to 20 years. This in turn means that in the foreseeable future, the available wood resources for felling will not decrease from what it is today in Latvia. And, given the fact, that leaving grown and overgrown forests by themselves, the wood loses its quality and its value decreases. It is possible to assume, that the logging activities in Latvia in the foreseeable future will not decrease. On the contrary, they will increase. It follows that, the raw wood material resources required for the production of various types of fuel wood (logs, pellets, wood briquettes, wood chips, etc.), in the foreseeable future should be available in the same amount as it is

Table 3

Final felling age (in years) depending on the site index in Latvia under 'Law on Forests'

Dominant tree species	Final felling age (in years) depending on the site index		
	I and higher	II-III	IV and lower
Oak	101	121	121
Pine and larch	101	101	121
Spruce, ash and lime-tree	81	81	81
Birch	71	71	51
Common alder	71	71	71
Aspen	41	41	41

Source: Meža likums, 2000.

Table 4

Latvian-produced fuel wood export (thousand solid cubic meters) in a division by type from year 2005 to year 2010

Type of fuel wood	Report year, thousand solid cubic meters					
	2005	2006	2007	2008	2009	2010
Firewood	372	418	450	495	740	805
Wood pellets	407	597	607	544	680	843
Woodchips	845	674	536	484	444	635
Wood briquettes	36	26	21	24	34	43
Wood residues	123	83	90	60	51	52
In total:	1782	1798	1705	1608	1949	2378

Source: made by the authors on the basis of LR CSB data.

today. This is undeniably dependant on the condition that in the foreseeable future there wouldn't be any unforeseen socio-economic developments, which significantly reduces the demand for wood products in export markets, which in turn could reduce the volume felled in Latvia.

Not of less importance, in the context of energy production is that large amounts of fuel wood are currently exported from Latvia (see Tab. 4). On the one hand, these amounts improve the Latvian foreign trading balance. On the other hand, they point to the potential of local fuel that could be used in Latvia.

Relating the total amount of fuel wood export (excluding transit) (see Tab. 4) to the total amount of fuel wood production in Latvia, a situation is indicated, where during the period from 2005 to 2009 the export share was 20% on average. But in 2010 it significantly increased, reaching 24.90%, which in principle means, that a quarter of fuel wood produced in Latvia during 2010 was being exported rather than used for domestic purposes.

2. An evaluation of the actual and future fuel wood use in district heating general use boiler houses and cogeneration plants in Latvia

Initially, it should be noted that, in accordance with the data compiled by LR CSB, in recent years in the total primary energy consumption structure of Latvia three types of energy resources dominate, taking about an equal share – oil products (year 2010 – 32.20% or 64.58 PJ), natural gas (year 2010 – 30.57% or 61.31 PJ) and fuel wood (year 2010 – 25.61% or 51.14 PJ). With this in mind, it is possible to argue that fuel wood is now a major domestic fuel in Latvia, while dominating the largest consumer is households, which, for example, in 2010 consumed a total of 4540 thsd. solid m^3 (thousand solid cubic meters) fuel wood, making up 61.95% of the total fuel wood consumption in 2010 in Latvia.

By assessing the state of primary energy resource use in district heating production in general use boiler houses and cogeneration plants in Latvia, a special emphasis should be on fact that at the moment they are practically dominated by natural gas (see Tab. 5). In general use cogeneration plants this dominance is absolute, but in general use boiler houses – very high.

It is important to emphasize, that in Latvia the active use of fuel wood in general use boiler houses for district heating began around 1993, when in conditions of absence of large primary resources, growing costs of fossil fuels, and decreasing consumer ability to pay, heating companies focused on the possibility of using fuel wood as cheap fuel. At that time, the transition to wider use of fuel wood was also contributed by the gradual development of the forest industry in Latvia, which generated substantial non-liquid residues. For instance, in 1990 only 436 TJ of fuel wood was consumed in general use boiler houses, ten years later (in 2000) it was 3191 TJ, while another ten years later (in 2010) – 4357 TJ (see Tab. 5). These changes have taken place mainly by replacing oil products and use of coal with wider use of fuel wood (mostly in the form of woodchips) (Meža īpašnieku iespējas..., 2011).

Evaluating the information shown in Table 5, it is possible to come to an evident conclusion, that there is still a great 'potential' for fuel wood (or other local fuel) use for district heating production in general use boiler houses in Latvia. And what is particularly essential, there are no technological limits at the moment for the transition from natural gas use in general use boiler houses to the use of a different energy resource. The main restrictive factor

Table 5

The primary energy resources (TJ (tera-joules)) used in district heating production in general use boiler houses and cogeneration plants in Latvia from 2005 to 2010

Position	Report year, TJ (tera-joules)					
	2005	2006	2007	2008	2009	2010
Boiler houses						
Natural gas	10565	8049	7333	7610	7105	6970
Fuel wood	3509	4081	4078	3901	3741	4357
Other energy resources	1838	862	776	572	776	567
In total:	15912	12992	12187	12083	11622	11894
Cogeneration plants						
Natural gas	21869	26193	24710	24236	23634	30842
Fuel wood	623	660	597	655	649	727
Other energy resources	663	655	896	679	881	801
In total:	23155	27508	26203	25570	25164	32370

Source: made by the authors on the basis of LR CSB data.

is the large amount of investments needed for such a transition, the limited capacity of local government to take on financial obligations, as well as the slow capital turnover rate in district heating companies (Siltumapgāde Latvijā, 2009).

Compared with general use boiler houses, the 'potential' of fuel wood (or other local fuel) use in cogeneration plants is even greater. But at this point hasty decisions should not be made. In essence, the very word 'cogeneration', which means the combined production of heat and electricity, indicates, that in order to completely understand the concept in Table 5, it is important not only to understand the situation in district heating, but also in the context of electric power supply. And it is the securing of national electric power supply that has been one of the main reasons for the establishment of natural gas as the main energy resource in general use cogeneration plants in Latvia. In particular, this applies to the first thermoelectric central in Riga (hereinafter – TEC-1) and Riga's second thermoelectric central (hereinafter – TEC-2), which belong to JSC 'Latvenergo', and is the most distinct example of why in the current condition of power supply of Latvia there is a need to preserve the highly effective cogeneration, which is provided by the use of natural gas as a fuel in the foreseeable future (Riga TEC-1 and TEC-2 (combined) consumed roughly 70% (therefore the dominating share) of the total natural gas consumption in general use cogeneration plants in Latvia in 2010). Just as important is to maintain a highly efficient cogeneration, provided by the use of natural gas as a fuel in other general use cogeneration plants, built in significant LR cities and provide cogeneration electric power production in large quantities.

Without going into details (such as fuel property evaluation, after which, by the way, biomass also is significantly 'behind' natural gas and fossil fuel as such), the approach described above is mainly related to the ratio between the produced electricity and thermal energy. Namely, to produce a part of electricity depending on the type of biomass, power plant capacity and technology, 3 to 5 parts of heat have to be produced, while using the well-proven and available technologies, intended for the use of biomass for energy production on an industrial scale. While using natural gas as a fuel in combined cycle gas turbine units (such technologies (combined cycle gas turbines (CCGT)) in Latvia have been installed in TEC-1 and TEC-2), the produced electricity ratio to heat can be a lot closer to '1 to 1' outcome and even achieve a reversed ratio. To put it simple, if natural gas as a fuel for the general use cogeneration plants would be replaced with biomass, then only taking into account the produced amount of energy (as opposed to price et al. nuances), with the existing heat loads (in case of cogeneration, electricity is generated according to the provided heat load), the produced quantity of electric power in Latvia would decrease considerably. A situation such as this would subject the national energy supply to particularly high risks. Because the 'base' capacity of electric power is already at a deficit, and it is predicted that in the foreseeable future electricity consumption in Latvia will strongly increase. Thus, based on accurate technically economic calculations (rather than a 'belief' in the additional economic benefits of RES use), there is a need to maintain highly efficient cogeneration in Latvia, which is provided by the use of natural gas as a fuel in general use in cogeneration plants. It is possible to familiarize with a detailed justification of this approach, for example, at the Institute of Physical Energetics, as well as in studies carried out by JSC 'Latvenergo'. At the same time we have to keep in mind that the electricity market in Latvia is open. Consequently, it is possible to argue that even from an elementary logic point of view, JSC 'Latvenergo' is interested in producing electricity, what can compete in the market of today (Meža nozares ieguldījums..., 2008; Energo Forums, 2011).

To evaluate the perspective (see the context of this word in the introduction of the study) use of fuel wood in district heating production in general use boiler houses and cogeneration plants in Latvia, it is necessary to identify projects predicting a wider use of fuel wood in substantial volumes (there is no considerable abandonment of fuel wood use in Latvia). The so-called 'serious projects', related to the development of new capacity for the fuel wood consumption in Latvia, are based on the engagement of co-financing from the European Union (hereinafter – EU) in structural funds, because without it theses projects would cost too much (the ratio of investment and projected benefit). In particular, we have to advert here to the EU support programs that existed / still exist in Latvia, such as: the activity 'Measures of increase the efficiency of district heat supply systems' (hereinafter – '3.5.2.1. activity') and the activity 'Development of cogeneration power plants using renewable energy resources' (hereinafter – '3.5.2.2. activity') financed by the EU Cohesion fund.

Based on the publicly available information the agreements signed between the Investment and Development Agency of Latvia and EU structural fund beneficiaries, a summary of the projects, which are approved in the planning period of 2007 to 2013 within '3.5.2.1. activity' and '3.5.2.2. activity' was made. From the perspective of a new fuel wood consumption quantity development, this information is a focused representation of the major projects (planned heat load is 7 MW (megawatts) or greater) and is shown in Table 6.

Table 6

The largest development projects for fuel wood consumption capacities with or in progress of receiving co-financing from the European Union's structural fund in Latvia for 25 January 2012

Project applicant	Project site	Planned project closure	Target capacity, MW		
			Heating	Electric	Total
JSC 'Rīgas siltums'	Tīraines street 5a, Rīga	03.2013.	22	4	26
JSC 'Rīgas siltums'	Kandavas street 16, Rīga	05.2013.	20	0	20
Ltd. 'Salaspils siltums'	Miera street 31a, Salaspils	05.1012.	7	0	7
Ltd. 'Tukuma siltums'	Asteru street 6, Tukums	11.2011.	10	0	10
Ltd. 'Fortum Jelgava'	Rūpniecības street 73, Jelgava	03.2013.	45	23	68
Ltd. 'Ventspils siltums'	Talsu street 69, Ventspils	07.2013.	20	0	20
Ltd. 'Enefit Power & Heat Valka'	Rūjienas street 5, Valka	01.2013.	9	2	11
Ltd. 'Cēsu siltumtīkli'	Rūpniecības street 12, Cēsis	06.2013.	7*	0	7*
Ltd. 'Liepājas enerģija'	Kaiju street 33, Liepāja	07.2013.	7.85	1.8	9.65
Ltd. 'Liepājas enerģija'	Kaiju street 33, Liepāja	06.2013.	30	0	30

* Plus an economizer with 1 MW capacity.

Source: made by the authors on the basis of Noslēgtie līgumi, 2012.

After an evaluation of information in Table 6 even without additional comments, it is clear that the demand for fuel wood in the domestic market (mostly woodchips) in the next few years will increase significantly, as new (both large and not so large) consumers of fuel wood will be active. For example:

- Ltd. 'Fortum Jelgava' estimate, that the necessary amount of woodchips will be around 450 thsd. solid m^3 to ensure the operation of the biofuel cogeneration plant in Rūpniecības street 73 (Jelgava). In the context of Latvia this is a very high quantity;
- JSC 'Rīgas siltums' estimate that the necessary amount of woodchips will be around 151719 solid m^3 to ensure the operation of 'Ziepniekkalns' (Rīga, Tīraines street 5a) biofuel cogeneration power unit. Likewise, this quantity is viewed as large in the context of Latvia (Noslēgtie līgumi, 2012).

Since there will be an additional volume of the fuel wood already consumed in Latvia, the provision of this amount could only be accomplished in three different ways or as a result of combining them:

- by increasing the production volumes of fuel wood in Latvia. The determining factor for such an eventuality to be truly realized, will be the increase of logging, because the raw materials of fuel wood are obtained at all stages of logging and woodworking as a by-product, rather than primary production;
- by shifting the fuel wood volumes meant for export to local markets. To truly realize such a possibility, local consumers in terms of discipline of solvency have to be able to compete with consumers outside Latvian borders. Or there is a need to create a more strict approach in the regulatory laws, promoting the use of the produced fuel wood for domestic purposes rather than export;
- by increasing the volume of imported fuel wood (in very small quantities, but a variety of fuel wood products are already being imported in Latvia, such as wood pellets from Belarus).

Given that:

- parallel to the projects included in Table 6 within the '3.5.2.1. activity' and '3.5.2.2. activity', there is a development of other similar projects in Latvia, with the only exception that the installed heat loads will not be so large;
- except for the projects developing within '3.5.2.1. activity' and '3.5.2.2. activity', there are other similar projects developing in Latvia (these are funded from company's assets and/or the use of Climate change financial instrument financing, and/or other provided financial instruments);
- Latvia is not the only country in Europe with large developing new projects for increasing used capacity of fuel wood.

It is possible to argue with a high probability that in the next few years in Latvia, rather than accomplishing one of the options mentioned above, but the combination of all options will occur.

Conclusions

1. If unexpected socio-economic developments do realize, raw wood material resources, required for the production of various types of fuel wood, in the foreseeable future in Latvia should be available at a quantity no less than they are today.

2. In the structure of primary energy resources used for district heating production in Latvia in general use:
   - boiler houses fuel wood have achieved a stable share – more than 30%;
   - cogeneration plants fuel wood is used in very small amounts – less than 3%.
3. There is a great 'potential' for fuel wood use in both general use boiler houses and cogeneration plants in Latvia, with one difference, under the existing conditions in Latvia's energy supply, this 'potential' in principle is only exploitable in general use boiler houses.
4. The consumption of fuel wood for district heating production in general use boiler houses and cogeneration plants in Latvia will increase significantly in the next few years; this increase will be especially 'felt' with the start of the 2013/14 heating season.

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References

1. Energo Forums (Energy Forum) *JSC 'Latvenergo' Electronic Journal No.3 (31)* Available at: http://www.latvenergo.lv/pls/portal/docs/PAGE/LATVIAN/EnergoForums1/EF_3_2011.pdf, 10 March 2012 (in Latvian).
2. Klāvs G., Kundziņa A., Ozoliņš J., Reķis J. (2010) Atjaunojamo energoresursu izmantošana Latvijas ilgtspējīgas attīstības nodrošināšanai (Use of Renewable Energy Resources for Ensuring a Stable Development of Latvia). Available at: http://www.sfl.lv/upload_file/2010%20gads/AER_petijums.pdf, 15 February 2012 (in Latvian).
3. Meža apsaimniekošana (Forest Management) (2012) State Forest Service. Available at: http://www.vmd.gov.lv/?sadala=2, 05 March 2012 (in Latvian).
4. Meža īpašnieku iespējas enerģētiskās koksnes tirgū (Possibilities of Forest Owners in the Wood Energy Market) (2011) AFO (Activating Private Forest Owners to Increase Forest Fuel Supply) project bulletin. Available at: http://www.afo.eu.com/default.asp?sivuID=26596&component=/modules/bbsView.asp&recID=20926, 25 February 2012 (in Latvian).
5. Meža likums (Law on Forests) (2000) The Law of the Republic of Latvia. Available at: http://www.likumi.lv/doc.php?id=2825, 10 March 2012 (in Latvian).
6. Meža nozares ieguldījums jauno Latvijas enerģētikas nozarei izvirzīto mērķu sasniegšanā (Contribution of the Forest Sector to Achieving the Newly Set Objectives for Latvia's Power Sector) (2008) Institute of Physical Energetics. Available at: http://www.zm.gov.lv/doc_upl/20_FEI_G.Klavs.pdf, 17 February 2012 (in Latvian).
7. Meža platība (Forest Area) (2010) Ministry of Agriculture Republic of Latvia. Available at: http://www.zm.gov.lv/doc_upl/meza_platiba.pdf, 3 March 2012 (in Latvian).
8. Noslēgtie līgumi (Concluded Contracts) (2012) Investment and Development Agency of Latvia. Available at: http://www.liaa.gov.lv/lv/es_fondi/es_fondi/noslegtie_ligumi_20072013plano/_gv/group-id_1488/, 15 February 2012 (in Latvian).
9. Siltumapgāde Latvijā (Heat Supply in Latvia) (2009) Latvian District Heating association. Available at: http://issuu.com/eaeaea/docs/ldha_book, 2 March 2012 (in Latvian).

ESTIMATION OF POTENTIAL IMPACT OF COASTAL EROSION PROTECTION IN LATVIA

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Abstract
The Baltic Sea problems in context of erosion always have been very topical and since ancient times have been caused by uncontrollable and unpredictable natural factors (storms). These factors combine with the impact of human economic activities of the direct effect of factors -building offshore and aquatorium, deficit of sediment and marine dredging and growth of recreational tourism growth that promote load of coastal vegetation and dune relief. The identification of costs and benefits is significant step for evaluation of the impact of the Project and usefulness of the costs. The positive impact or benefits can occur at once, after a while or long term perspective. The economic evaluation techniques particularly cost-benefit and cost-effectiveness analysis for coastal protection in this case used for ascertain the most effective alternative. The sensitivity analysis was made for verifying impact of alternatives on taken solution. The aim of research is to verify the economic methods for application to coastal management in Latvia. The world's coastal scientists believe that the future of coastal policy will become increasingly polarized and discussed; therefore, gradual implementation of the assessment process and development of socio-economic indicators is recommended.
Key words: Regional development, coastal erosion protection, costs and benefit analyses, environmental economics.

Introduction

Any sustainable economic development is based on effective site management and integrated regional development, including development of coastal regions. It is important to note that the total length of Latvian coastal area covers the third of the total borderline of the State (about 26%) and population already approaching 1 million people in 5-10 km wide coastal zone. Based on the monitoring data of the past century, the coast is washed up to 200 m. As a result, the Sea is dangerously approaching originally built villages, individual farms and cities (Eberhards et al., 2009).

The Baltic Sea problems in context of erosion always have been very topical and since ancient times have been caused by uncontrollable and unpredictable natural factors (storms). Over time this problem is getting more topical in particular because of the changes in natural processes, which more or less are connected with climate changes that influence the growth of storm force, rise of global water level, more intense wash out of sand, etc. These factors combine with the impact of human economic activities of the direct effect of factors - building offshore and aquatorium, deficit of sediment and marine dredging and growth of recreational tourism growth that promote load of coastal vegetation and dune relief (Lapinskis, 2010).

Despite the topicality of the problem, Latvia still lacks real estimate of the economic losses in the national economy resulted from erosion and also lack of policy regarding coastal erosion prevention.

As the process of environmental changes has become more intense both locally and globally, thus the risks for ecosystem resilience and integrity have become greater, particularly in coastal areas. Within the development of EU environmental protection and management policy there is an increasing need for economical evaluation of environmental ecosystems. The main driving force of economical evaluation is EU Water Framework Directive which is very important in introducing economic aspects in development of water protection and management policy. EU Water Framework Directive states that in case of loss protected areas compensation must take place on the principle of equivalence. For example, in decision – making process related to water protection the socio-economic conditions, including costs and benefits of political decisions and actions while estimating situations can be taken into account (Pakalniete et al., 2008).

The authors of article for estimating losses of coastal erosion propose to apply the method of cost-benefit analysis, mathematically calculating the benefits of economic activities and environmental aspects of coastal area and losses of coastal erosion.

Materials and Methods

For estimation of Latvia coastline it was necessary to define all coastal values and distribute them in calculation classes. It is done based on socio-economical indicators, analysis of Latvian coastline and developed methodology for estimating values.

To estimate coastal values, the methodology based on benefit transfer method (Wilson et al., 2006;

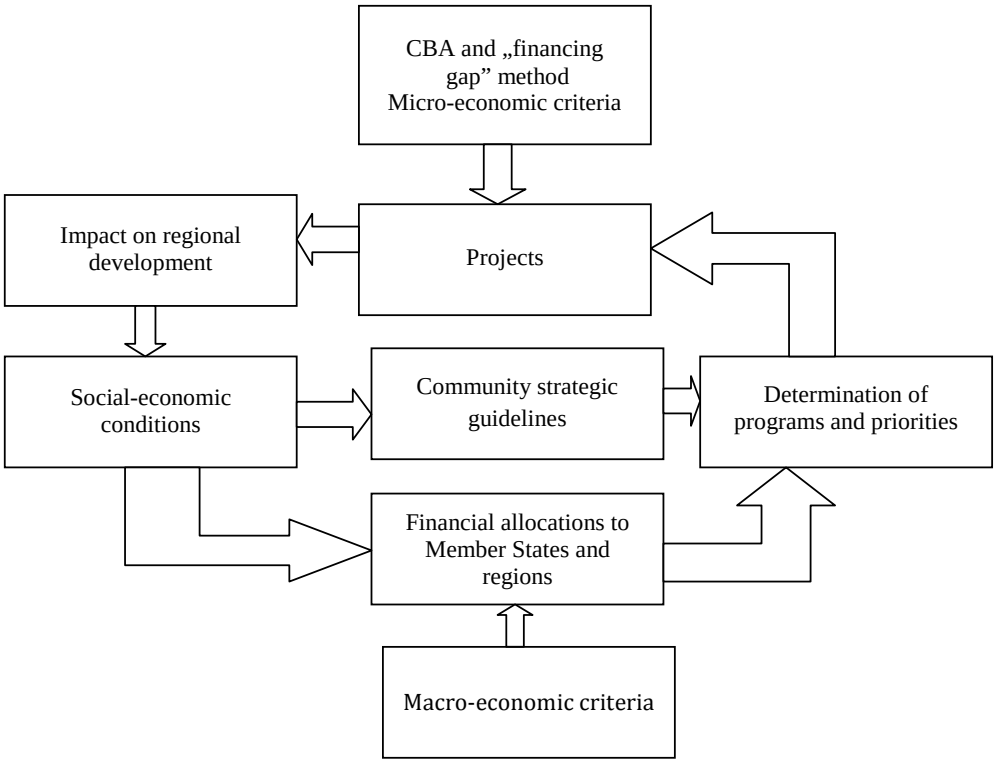

Figure 1. Application of CBA for return of investments of regional development projects.

Martineza et al., 2007; Brenner et al., 2010), method of estimating market value and cadastral value of land were applied.

Costs – benefit analysis (CBA) is a quantitative method for evaluation of public projects. It is applied to determine:

- the best possible alternative;
- impact of the project on the region where it takes place
- risks of the Project and its financial and economic impact (Roebeling et al., 2011).

The identification of costs and benefits is a significant step for evaluation of the impact of the Project and usefulness of the costs. The positive impact or benefits can occur at once, after a while or in a long term perspective. This method is more often used for evaluation infrastructure or capital investment projects. In Figure 1, an application of CBA for return of investments of regional development projects that we consider to be also sustainable coastal protection is shown. The authors of the article follow CBA application scheme as follows:

Overall, the benefits of cost-benefit analysis can be classified as follows:

- tangible benefits - expressed in terms of money. For example, new working places, reduced for certain social groups;
- intangible benefits – difficult to express in terms of money, but they are often quantities in units of time, health, comfort, environmental or cultural factors. For example, successful implementation of public relation in long term provides positive effect on target groups and society in general;
- administrative benefits arise in a way of providing and improving state administrative functions, for example, merging two separate institutions, reducing costs, etc. (Turnera et al., 2007).

Results and Discussion

The economic evaluation techniques particularly cost-benefit and cost-effectiveness analysis for coastal protection in this case were used to ascertain the most effective alternative.

To determine costs and benefits of coastal erosion, the net present value for certain district where coastal protection is plannedwas estimated. It was estimated as follows:

$$NPV = \sum_{t=0}^{T} \frac{L_t}{(1+r)^t} - \sum_{t=0}^{T} \frac{Z_t}{(1+r)^t} \quad (1)$$

where Z – costs of coastal protection and value of land lost in process of coastal erosion. LVL
t – time period
r – discount rate
L – value of total land protected, LVL

The discount rate, labour, material and maintenance expenses were taken into account for 20- year time period.

Authors have approbated the developed methodology on an example of waste water treatment plants in Liepaja city. Authors were experts in EU co-financed Cohesion "Consulting services for coastal protection against erosion in Liepaja" from 2007 to 2009 (Brūniņa, 2011).

The Liepaja city waste water treatment plants (WWTP) are located on the coast of the Baltic Sea, about 7km to north of the city. There is a vast erosion along coastline where waste water treatment plants have been located, and it will threaten the operation of plants in the future.

About 15 years ago, „symbolic" coastal protection structures consisting of two walls of used tires based on wooden piles and steel wires were built. However, the strong storm in January, 1999 and January, 2005 and 2007 washed away most of these structures and washed out a significant section of the dunes behind them (Bethers et al., 2009).

Based on analysis of coastal processes and possible future development of this coastal zone, the problem of this kind as well as alternatives for protection of coast near existing treatment plants and construction of new treatment plants output into the Sea were defined.

In order to find the best as well as economically and technically justified solution where technical, maintenance, environmental protection and economic aspects were taken into account, more than 20 alternatives and sub-alternatives were evaluated. As a result, three most appropriate alternatives were selected:

- Construction of 500 m long Jetty in the northern direction of waste water treatment plants combinedwith one-time initial beach nourishment in amount of 100000 m^3 in WWTP area (1.9. alternative)
- Annual beach nourishment 100000 m^3 $year^{-1}$ depositing at the zone in front of WWTP (3.4.alternative)
- transfer of port dredged sand dump in front of Liepaja waste water treatment plants and regular beach nourishment with vessel (3.5.alternative).

In 2009, CBA was applied only for two alternatives – 1.9. and 3.4. Other alternatives were turned down as impossible for regional politics or technical – economical reasons (Bethers et al., 2009). It is important to emphasize that applied CBA does not include all impacts of project results, including loss of coastal land and environmental values.

Authors propose methodology for evaluating coastal erosion projects and have applied CBA for three alternatives, assuming that all future revenues are proportionally distributed in 50 - year time period. According to European Commission guidelines for environment investment projects, the discount rate was assumed to be 5%.

The costs of 0 (status quo) alternative for Liepaja project is shown in Table 1.

Table 1

Estimation of costs of „0" alternative

Estimation	Prognosis of „0" alternative for 50 years in prices of 2012	
E	Area m^2	Value, LVL
A	-	0.00
F	120000 (3.b-Zforts)	124020,00
N	70000	119000,00
P	-	0.00
R	120000	17989226,00
I	Road – 150 m^2; gabions– 8300 m^2	84500,00
H	30000	15095,50
B	60000	210000,00
In total	**-**	**18541842,00**

Source: Cerated by the authors.

To compare alternatives, difference between obtained and lost coastal areas taking into account optimistic prognosis or minimal coastal erosion (shown in Table 2) was calculated.

To determine all the benefits for CBA calculations, the accumulated coastal area as the result of coastal protection in certain coastal zone near treatment plants

Table 2

Estimation of obtained and lost coastal areas of alternatives

The total balance, ha	„0" alternative	1.9. Jetty	3.4. nourishment	3.5. nourishment
Eroded areas - E	40	53	6	2
Accumulated areas - G	0	10	25	38
Obtained/lost areas – T	**-40 ha**	**-43 ha**	**+19 ha**	**+36 ha**

Source: Crated by the authors.

Table 3

Value of obtained/lost areas, LVL

Alternative	Jetty 1.9.		3.4. nourishment		3.5. nourishment	
E	G_{ka}	E_{ka}	G_{ka}	E_{ka}	G_{ka}	E_{ka}
A – dry meadows	-	370125	-		-	-
F – pine forest	-	227370	-	51675	-	-
N – gray dune, Nature park "Medze"	-	80000	-	5100	-	10200
P – 3 private household	-	122500	-	-	-	-
R	-	-	-	-	-	-
I - road	-	20000	-	-	-	-
H – not viewed	-	-	-	-	-	-
B – beach	350000	157500	875000	24500	1330000	24500
In total, LVL	350000	977495	875000	81275	1330000	34700

Source: Created by the authors.

and eroded areas adjacent sections of the coast was estimated. The value of lost areas based on benefit transfer method, travel costs method and analysis of market price and cadastral values was estimated.

To estimate value of meadows, it is assumed that the 2.5 tons are produced from 1 ha and hay price is 250 LVL t^{-1}. Since there is no economic activity in coastal meadows, they can be considered as natural values, so benefit transfer method - 1.4 LVL m^{-2} can be applied. To calculate private property, the cadastral value 10 LVL m^{-2}, average the size of one household 2500-3500 m^2 is taken.

Table 4

Cost benefit analysis for selected alternatives

Alternatives and variations to the various factors	Discount rate 3%	Discount rate 5%	Coefficient 2[1] at discount rate 3%	Coefficient 2 at discount rate 5%
Jetty – average of income	728974,07	-1533637,58	10213618,08	5358771,57
Jetty – income after 10 years	-1226436,89	-3457442,72	7078296,35	1514404,60
Jetty – income after 20 years	-2153453,14	-4785008,22	4549247,10	-1138735,45
3.4. Nourishment – average of income	263357,37	353709,46	10157797,25	12668552,16
3.4. Nourishment – income after 10 years	-944749,66	-1568474,11	7022475,26	3405951,66
3.4. Nourishment – income after 20 years	-2209274,23	-2895044,11	4493426,12	752811,66
3.5. Nourishment of the elevated road – average of income	2678758,23	1470709,66	12213644,14	7631128,91
3.5. Nourishment of the elevated road – income after 10 years	1111097,23	-2713383,08	9078322,15	4522951,85
3.5. Nourishment of the elevated road – income after 20 years	-3280622,86	-1778043,92	6549273,01	1869811,85
3.5. Nourishment of vessel – average of income	3388928,40	2312872,67	9209482,01	8473291,92
3.5. Nourishment of vessel – income after 10 years	1821267,40	390689,09	9788492,32	5365114,86
3.5. Nourishment of vessel – income after 20 years	390689,09	-935880,91	7259443,19	2711974,86

Source: Created by the authors.

1 e Coeficient 2 is applied, construction of new WWTP

A cost benefit analysis shows that the most advantageous option is beach nourishment; shifting sand dump in front of Liepaja WWTP (3.5.noursihment of the vessel), and most disadvantageous version is Jetty building and beach nourishment from the coast. With the help of the CBA quantitative indicators were obtained, the effectiveness of alternative assessment sensitivity analysis was used.

The sensitivity analysis was made for verifying impact of alternatives on taken solution. Sensitivity analysis was carried out at different discount rates - 3, 5, 7, 10%, as well as the calculation of the repayment schedule of various revenue which will be recovered after 10 and 20 years. as Also, the calculation was made to factor 2 (WWTP loss value is doubled) to be applied in case if Liepaja WWTP is completely washed during next 50 years, and it is necessary to construct a new WWTP at another location.

The sensitivity analysis shows that the lowest sensitivity at changes of discount rate and return of revenues has alternative of beach nourishment from port fairway, but the largest for alternative - construction of Jetty. It means that the alternative – jetty is the project with the smallest or most unstable viability.

Multi-criteria analysis is a method for assessing the effectiveness of alternatives taking into account several aspects, for each of them giving its own weight (Kļaviņa, 2005). The method is useful for defining the policy priorities in any field, but it can also be used as

Table 5

Multicriteria analysis of project

Project Jetty alternative 1.9			
Criteria	Points	Level of significance	Impact
Protection of socio-cultural values	2	0.8	1.6
Nature landscape and heritage of generations	0	0.5	0
Saving of annual maintenance cost to local government or business budget	3	0.6	1.8
Increasing of administrative capacity of local municipalities, improvement of citizens' knowledge	1	0.3	0.3
Diversification of economic activities and sustainable management of coastal regions	1	0.4	0.4
Ecological services of ecosystems	0	0.2	0
Positive balance of land areas	1	0.4	0.4
Social justice	1	0.5	0.5
Equal opportunities	2	0.2	0.8
Environment protection	0	0.4	1.6
Total			5.8 – significant impact
Project Nourishment alternative 3.4			
Protection of socio-cultural values	4	0.8	3.2
Nature landscape and heritage of generations	4	0.5	2
Saving of annual maintenance cost to local government or business budget	0	0.6	0
Increasing of administrative capacity of local municipalities, improvement of citizens' knowledge	2	0.3	0.6
Diversification of economic activities and sustainable management of coastal regions	2	0.4	0.8
Ecological services of ecosystems	4	0.2	0.8
Positive balance of land areas	4	0.4	1.6
Social justice	2	0.5	1
Equal opportunities	1	0.2	0.2
Environment protection	1	0.4	0.4
Total			10.4 – very significant impact

Source: Created by the authors.

a supplement of cost-benefit analysis in cases when it is important to consider such factors which cannot be evaluated in CBA, for example social justice. A pair comparison method for determining criteria for multi-criteria analysis was applied.

Although 3.5 alternative (nourishments from port fairway) shows the lowest sensitivity at changes of discount rate and is only positive at return of revenues after 10 years, alternative 1.9 (Jetty) shows the largest sensitivity at changes of discount rate and return of revenues after 20 years. To evaluate both project solutions (alternative 1.9 and 3.5), the multi-criteria analysis method (Table 5.) was used.

The multicriteria analysis shows of 4.6 points greater prevalence of implementation of nourishments alternative. The largest value of Jetty alternative is 1.8 points were for criteria of saving of annual maintenance cost to local government or business budget. Regarding nourishments alternative, two criteria exceed 1.8 - Protection of socio-cultural values (3.2) and Nature landscape and heritage of generations (2).

Conclusions

The losses due to coastal erosion in the time period of 50 years will reach 18,541,842.00 LVL in the area of Liepaja city. It is possible to conclude that in our example of Liepaja WWTP, building of jetty in 500m of length and 7 meters of depth had turned out as „lowest price" alternative against beach nourishment. Such a situation – selection of non-economical solution mainly was caused by a lack of common strategy and motivation to cooperate at a national, regional as well as local level. The analysis made by authors shows that in case Liepaja does not get state support for transfer port dredged sand dump closer to shallow water zone, more optimal is alternative 3.4. compared to Jetty alternative 1.9. There are less negative indicators of net present value; it is positive at discount rates 3% and 5% against Jetty, which have negative reduced value at discount rate 5%.

The world's coastal scientists believe that the future of coastal policy will become increasingly polarized and discussed; therefore, gradual implementation of the assessment process and development of socio-economic indicators is recommended. The losses due to coastal erosion will increase if inappropriate protective measures are chosen. For example, in Liepaja city the land area of more than 40 ha would erode in case of jetty alternative, but if the alternative of nourishment was implemented, the accumulation of land would be from 19 to approximately 40 ha. This is a very problematic issue which is not properly considered by the Latvian government.

Initially, it is necessary to identify all areas where costs of coastal protection alternatives are not related to social justice, environmental protection or ethical considerations. In such cases, the costs will be related to loss of lower quality agricultural or forestry land, and the costs can be estimated by the CBA method.

We are considering that in cases when human factors, property rights, cultural heritage and nature conservation areas as cost-determining aspects of alternatives aspects are involved, the CBA results will not be crucial and it would be useful to apply other additional methods - sensitivity analysis and multi-criteria analysis. On the other hand, authors believe that in order to apply the above discussed methods, political documents on base of which acceptance or rejection of decision can take place are necessary.

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References

1. Bethers U., Brunina L., Eberhards G., Gobiņš J. (2009) Final report of Project "Consultant services for coastal protection against erosion", pp. 12–37.
2. Brenner J., Jiménez José A., Sarda R., Garola A. (2010) An assessment of the non-market value of the ecosystem services provided by the Catalan coastal zone, Spain. *Ocean & Coastal Management,* 53, pp. 27–38.
3. Brunina L. (2011) Measurement Methodology of Losses Due Erosion of Coastal Area in Latvia. Economics and Rural Development, Latvia University of Agriculture, Faculty of Economics, Jelgava, Latvia, pp. 6–13.
4. Brunina L. (2010) Problems of Coastal Erosion Prevention in Latvia. *Coastal Evolution Studies: Traditions and Modern Concepts*: Proceedings of International Coastal Conference. Publisher, RSHU, Saint-Petersburg, Russia, pp. 1–7.
5. Eberhards G., Grine I., Lapinskis J., Purgalis I., Saltupe B., Torklere A. (2009) Changes in Latvia's seacoast (1935-2007). Baltica, 22 (1), Vilnius. ISSN 0067-3064. pp. 11–22.
6. EIROPAS KOMISIJA, REĢIONĀLĀS POLITIKAS ĢENERĀLDIREKTORĀTS (2006) Nozaru attīstība, ietekme, novērtēšana un jauninājumi Novērtēšana un papildināmība Jaunais plānošanas periods 2007. – 2013. (European Commission, DG Regional Policy, Guide to cost-benefit analysis of investment

projects). Metodiskie norādījumi izmaksu un ieguvumu analīzes veikšanai, Available at: http://ec.europa.eu/regional_policy/sources/docoffic/2007/working/wd4_cost_lv.pdf, 16 May 2006 (in Latvian).
7. Lapinskis J. (2010) Baltijas jūras Kurzemes krasta dinamika. (Kurzeme's coast dynamic of the Baltic Sea). Promocijas darbs doktora grāda iegūšanai ģeoloģijas nozares kvartārģeoloģijas un ģeomorfoloģijas apakšnozarē, pp. 35–79. (in Latvian).
8. Pakalniete K., Malzubris J. (2008) Ieguvumu pārneses metodes izmantošana ūdeņu ekosistēmu ekonomiskā novērtēšanā (Using the Benefits of the Transfer Method for Economic Valuation of Aquatic Ecosystems.) *LATVIJAS UNIVERSITĀTES RAKSTI,* 721, pp. 312–331. (in Latvian).
9. Kļaviņa S., Klapkalne U., Pētersone B. (2005) Politikas ietekmes vērtēšana politikas veidošanas sistēmā. (Assessment of political impact on the development of political system) Valsts kanceleja ISBN 9984-684-29-6, 2005, Jelgavas tipogrāfija, pp. 22–49. (in Latvian).
10. Roebeling P.C., Coelho C.D., Reis E.M. (2011) Coastal erosion and coastal defense interventions: A cost benefit analysis. *Journal of Coastal Research, Special Issue,* 64, pp. 1415–1419.
11. Martínez M.L., Intralawan A., Vázquez G., Pérez-Maqueo O., Sutton P., Landgrave R. (2007) The coasts of our world: Ecological, economic and social importance. *ECOLOGICAL ECONOMICS,* 63, pp. 254–272.
12. Turner R.K., Burgess D., Hadley D., Coombes E., Jackson N. (2007) A cost–benefit appraisal of coastal managed realignment policy. *Global Environmental Change,* 17, pp. 397–407.
13. Wilson M.A., Hoehn J.P. (2006) Valuing environmental goods and services using benefit transfer. *The state-of-the art and science//Ecological Economics,* 60, pp. 335–342.