



ONLINE ISSN 2255-923X
ISSN 1691-4031



Latvia University
of Life Sciences and Technologies

Volume 35

Annual 26th International
Scientific Conference
**Research for Rural
Development
2020**





Latvia University of Life Sciences and Technologies

**RESEARCH
FOR
RURAL DEVELOPMENT 2020**

Annual 26th International Scientific Conference Proceedings

**Volume 35
Jelgava 2020**



LATVIA UNIVERSITY OF LIFE SCIENCES AND TECHNOLOGIES

ONLINE ISSN 2255-923X
ISSN 1691-4031

RESEARCH FOR RURAL DEVELOPMENT 2020
http://www2.llu.lv/research_conf/proceedings.htm

May, 2020

ORGANISING TEAM

Ausma Markevica, Mg.sc.paed., Mg.sc.soc., Mg.sc.ing., Research coordinator, Research and Project Development Center, Latvia University of Life Sciences and Technologies

Zita Kriaučiūniene, Dr.biomed., associate professor, Vytautas Magnus University, Agriculture Academy, Lithuania

Nadežda Karpova-Sadigova, Mg.sc.soc., Head of Document Management Department, Latvia University of Life Sciences and Technologies

SCIENTIFIC COMMITTEE

Chairperson

Zinta Gaile, professor, Dr.agr., Latvia University of Life Sciences and Technologies

Members

Irina Arhipova, vice-rector for science, professor Dr.sc.ing., Latvia University of Life Sciences and Technologies

Andra Zvirbule, Dr.oec., professor, Latvia University of Life Sciences and Technologies

Gerald Assouline, associate professor, Dr.sc. soc., Director of QAP Decision, Grenoble, France

Inga Ciproviča, professor, Dr.sc.ing., Latvia University of Life Sciences and Technologies

Signe Bāliņa, professor, Dr.oec., University of Latvia

Aivars Kaķītis, professor, Dr.sc.ing., Latvia University of Life Sciences and Technologies

Antanas Dumbrasukas, associate professor, Dr.sc.ing., Vytautas Magnus University, Lithuania

Āris Jansons, associate professor Dr.silv., Latvia University of Life Sciences and Technologies, senior researcher, Latvian State Forest Research Institute "Silava"

Ilmārs Dukulis, profesor, Dr.sc.ing., Latvia University of Life Sciences and Technologies

Jan Žukovskis, professor, Dr.oec., Vytautas Magnus University, Lithuania

TECHNICAL EDITORS

Santa Treija


Signe Skujeniece

© Latvia University of Life Sciences and Technologies, 2020

The ethic statements of the conference 'Research for Rural Development 2020' are based on COPE's Best Practice Guidelines: http://www2.llu.lv/research_conf/proceedings.htm

DOI and similarity check:



Approved and indexed: The Proceedings of previous Annual International Scientific Conferences 'Research for Rural Development' published by Latvia University of Life Sciences and Technologies since 1994 and has been approved and indexed in to databases: AGRIS;  CAB ABSTRACTS; CABI full text; EBSCO Academic Search Complete; Scopus; Web of Science TM, Clarivate Analytics /former Thomson Reuters; Primo Central (Exlibris)...

Editorial office: Latvia University of Life Sciences and Technologies, Lielā ielā 2, Jelgava, LV-3001, Latvia
Phone: + 371 630 05685; e-mail: Ausma.Markevica@llu.lv



LATVIA UNIVERSITY OF LIFE SCIENCES AND TECHNOLOGIES

ONLINE ISSN 2255-923X
ISSN 1691-4031

RESEARCH FOR RURAL DEVELOPMENT 2020
http://www2.llu.lv/research_conf/proceedings.htm

May, 2020

FOREWORD

The Latvia University of Life Sciences and Technologies and Organizing Committee of Annual 26th International Scientific Conference '*Research for Rural Development 2020*' tried to continue a tradition of bringing together researchers, academic and professionals in Jelgava, from 13 to 15 May, 2020 from all over the world. But, unfortunately, this year the rules were set by the Covid -19 virus pandemic.

We did start new tradition from 2020, account from 1st until the 26th conference and totally are 35 Volumes.

The interdisciplinary papers contributed the most recent scientific knowledge in crop production, animal breeding, agricultural engineering, agrarian and regional economics, food sciences, veterinary medicine, forestry, wood processing, water management, environmental engineering, information and communication technologies.

These Proceedings will furnish the scientists of the world with an excellent reference volume. We trust also that this will be an impetus to stimulate further study and research in all these areas.

We thank all authors for their contributions.

We thank you for your interest in the Conference '*Research for Rural Development 2020*' and look forward to the 27th conference in 2021.

Ausma Markevica
Chairperson
Annual 26th International Scientific Conference
'*Research for Rural Development 2020*'

CONTENTS

AGRICULTURAL SCIENCES	Agrita Švarta, Gunita Bimšteine, Zinta Gaile, Terēze Stanka, Linda Daugaviņa, Ieva Plūduma-Pauniņa	
	DEVELOPMENT OF WINTER WHEAT BLOTCHES DEPENDING ON FUNGICIDE TREATMENT SCHEMES AND NITROGEN RATES	7
	Madara Darguza, Zinta Gaile	
	THE EFFECT OF CROP ROTATION AND SOIL TILLAGE ON WINTER WHEAT YIELD	14
	Volodymyr Mezhenskyj, Tetiana Kondratenko, Borys Mazur, Nataliia Shevchuk, Yurii Andrusyk, Oksana Kuzminets	
	RESULTS OF <i>RIBES</i> BREEDING AT THE NATIONAL UNIVERSITY OF LIFE AND ENVIRONMENTAL SCIENCES OF UKRAINE	22
	Līga Feodorova-Fedotova, Biruta Bankina	
	OCCURRENCE OF GENETIC LINEAGES OF <i>PUCCINIA STRIIFORMIS</i> IN LATVIA	27
FORESTRY AND WOOD PROCESSING	Daiva Tiškutė-Memgaidienė, Gintautas Mozgeris, Algis Gaižutis	
	OPEN GEO-SPATIAL DATA FOR SUSTAINABLE FOREST MANAGEMENT: LITHUANIAN CASE	33
	Baiba Jansone, Linards Sisenis, Irina Pilvere, Marcis Vinters, Karlis Bickovskis	
	INFLUENCE OF DRAINAGE RECONSTRUCTION ON RADIAL INCREMENT OF CONIFERS: CASE STUDY	42
	Aldis Butlers, Andis Lazdins	
	CARBON STOCK IN LITTER AND ORGANIC SOIL IN DRAINED AND NATURALLY WET FOREST LANDS IN LATVIA	47
	Oto Rums, Inga Straupe, Leonīds Zdors, Jānis Donis	
	COMPARISON OF REGENERATION OF SCOTS PINE <i>PINUS SYLVESTRIS</i> L. IN <i>MYRTILLOSA</i> AND <i>HYLOCOMIOSA</i> FOREST TYPES AFTER SHELTERWOOD CUTTINGS	55
	Agris Zimelis, Santa Kalēja, Sergey Ariko	
	EVALUATION OF PRODUCTIVITY AND COSTS OF MALWA FOREST MACHINE IN SANITARY FELLINGS IN LATVIA	61
	Aigars Strubergs, Andis Lazdins, Linards Sisenis	
	EVALUATION OF COMPLIANCE OF EXISTING FOREST MACHINE INFORMATION SYSTEMS FOR THE IMPLEMENTATION OF THE STANDART STANFORD 2010	66
Matiss Pals, Līga Lauberte, Alexandr Arshanitsa, Laima Vevere, Vilhelmine Jurkjane, Galina Telysheva		
ORGANOSOLV DELIGNIFICATION OF RESIDUAL PLANTATION WILLOW BARK AFTER EXTRACTIVE REMOVAL	73	
Ilze Karklina, Zaiga Anna Zvaigzne, Jeļena Stola		
CHEMICAL PROPERTIES OF NEEDLES AS AN INDICATOR OF NUTRIENT STATUS OF FERTILIZED CONIFEROUS STANDS	80	
Alexandr Arshanitsa, Jevgenija Ponomarenko, Maris Lauberts, Vilgelmina Jurkjane, Lilija Jashina, Alexandr Semenischev, Jegor Akishin, Galyna Telysheva		
COMPOSITION OF EXTRACTS ISOLATED FROM BLACK ALDER BARK BY MICROWAVE ASSISTED WATER EXTRACTION	87	
Daniela Godina, Ralf Pomilovskis, Nadezda Iljina, Kristine Meile, Aivars Zhurinsh		
PYROLYSIS AND ACID HYDROLYSIS OF LIGNOCELLULOSIC BIOMASS AS A TOOL FOR MONOSACCHARIDE OBTAINING	95	

FOOD SCIENCE	Ukilim Tastemirova, Inga Ciprovica, Azaret Shingisov	
	THE COMPARISON OF THE SPRAY-DRYING AND FREEZE-DRYING TECHNIQUES FOR CAMEL MILK: A REVIEW	102
	Sanita Vucane, Martins Sabovics, Lauris Leitans, Ingmars Cinkmanis	
	SMARTPHONE-BASED COLORIMETRIC DETERMINATION OF DPPH FREE RADICAL SCAVENGING ACTIVITY IN VEGETABLE OILS	106
	Anete Keke, Ingmars Cinkmanis	
	α -AMYLASE ACTIVITY IN FREEZE-DRIED AND SPRAY-DRIED HONEY	112
VETERINARY MEDICINE	Alla Mariseva, Ilze Beitane	
	ASSESSMENT OF INGREDIENTS AND NUTRITIONAL VALUE OF VEGAN PRODUCTS IN LATVIAN MARKET	118
	Ieva Rasskazova, Asnate Kirse-Ozolina	
	FIELD PEA <i>PISUM SATIVUM</i> L. AS A PERSPECTIVE INGREDIENT FOR VEGAN FOODS: A REVIEW	125
	Santa Puke, Ruta Galoburda	
FACTORS AFFECTING SMOKED FISH QUALITY: A REVIEW	132	
ECONOMICS	Olga Ponomarjova, Ilga Sematovica, Inga Piginka-Vjaceslavova, Aida Vanaga	
	CATTLE (<i>BOS TAURUS</i>) ENDOMETRIUM MORPHOLOGY ON THE SEVENTH DAY OF THE ESTROUS CYCLE	140
	Lina Marcinkevičiūtė, Jolanta Vilkevičiūtė, Jan Žukovskis	
	LEGAL AND MANAGERIAL SOLUTIONS OF PUBLIC SECTOR AUTHORITIES FOR PRESERVING ECOSYSTEM SERVICES OF THE LAKES	146
	Iluta Berzina, Edgars Balodis	
	TESTING AN OPERATION OF PROTOTYPE FOR AUTOMATED ASSESSMENT: CASE OF VISITOR PROFILE OF GAUJA NATIONAL PARK	154
	Vytautas Pilipavičius, Jan Žukovskis	
	DEVELOPMENT OF ECOSYSTEM SERVICE OPPORTUNITIES IN THE NEMUNAS DELTA IN THE CONTEXT OF GLOBAL CLIMATE CHANGE	162
	Rolandas Drejeris, Mindaugas Samuolaitis	
	DEVELOPMENT OF SUSTAINABLE DISTRIBUTION LOGISTIC SYSTEM	169
	Agnė Žičkienė	
RESILIENCE IN AGRICULTURE: HOW CAN CAP DIRECT PAYMENTS IMPACT IT?	176	
Sanita Bethere, Lasma Licite-Kurbe		
CHALLENGES IN HUMAN RESOURCE MANAGEMENT IN THE CULTURE INDUSTRY IN LATVIA	183	
Aija Pilvere-Javorska, Irina Pilvere, Baiba Rivža		
COMPANY CAPITAL STRUCTURE THEORETICAL FRAMEWORK: HISTORICAL ASSESSMENT AND TRENDS IN THE 21 ST CENTURY	191	
Miglė Šontaitė-Petkevičienė		
CUSTOMER-BASED BRAND EQUITY CREATION FOR ONLINE GROCERY STORES	199	
RURAL AND ENVIRONMENTAL ENGINEERING	Dainora Jankauskienė, Indrius Kuklys, Lina Kuklienė, Birutė Ruzgienė	
	SURFACE MODELLING OF AN UNIQUE HERITAGE OBJECT: USE THE UAV COMBINED WITH CAMERA AND LIDAR FOR MOUND INSPECTION	207
	Giedrė Ivavičiūtė	
	THE CHANGE OF NATURAL LANDSCAPE IN LITHUANIA	213

RURAL AND ENVIRONMENTAL ENGINEERING	Juris Burlakovs, Jovita Pilecka, Inga Grinfelde, Ruta Ozola-Davidane	CLAY MINERALS AND HUMIC SUBSTANCES AS LANDFILL CLOSURE COVERING MATERIAL CONSTITUENTS: FIRST STUDIES	219
	Edvins Grants	A SURVEY OF STATISTICS OF BUILDING FIRES IN LATVIA	227
	Janis Fabriciuss, Lilita Ozola	DURATION OF LOAD EFFECTS ON DEVELOPMENT OF DEFORMATIONS IN BOLTED MOMENT CONNECTION	234
WATER MANAGEMENT	Kristīne Ikauniece, Ainis Lagzdīš	THE ASSESSMENT OF CHEMICAL AND ECOLOGICAL STATUS IN THE WATER BODIES OF SLOČENE AND AGE	241
	Janis Ivanovs, Toms Stals, Santa Kaleja	IMPACT OF THE USE OF EXISTING DITCH VECTOR DATA ON SOIL MOISTURE PREDICTIONS	248
INFORMATION AND COMMUNICATION TECHNOLOGIES	Nikolajs Bumanis	DATA FUSION CHALLENGES IN PRECISION BEEKEEPING: A REVIEW	252
	Ilja Arefjevs, Aivars Spilbergs, Andris Natrins, Atis Verdenhofs, Inese Mavlutova, Tatjana Volkova	FINANCIAL SECTOR EVOLUTION AND COMPETENCIES DEVELOPMENT IN THE CONTEXT OF INFORMATION AND COMMUNICATION TECHNOLOGIES	260
	Nikolajs Bumanis, Gatis Vitols, Irina Arhipova, Inga Meirane	DEEP LEARNING SOLUTION FOR CHILDREN LONG-TERM IDENTIFICATION	268
EDUCATION	Marina Troshkova, Irena Katane	THEORETICAL SUBSTANTIATION OF THE COMPETITIVENESS OF ACADEMIC STAFF FROM THE PERSPECTIVE OF EDUCATIONAL SCIENCES	274
	Aleksandra Jerkunkova, Irena Katane, Regina Baltusite	CHANGES IN THE ENGINEERING STUDENTS' PROCRASTINATION SELF-EVALUATION WITHIN THE EXPERIMENTAL APPROBATION OF CAREER EDUCATION PROGRAM	282
	Sandra Kreija-Gaikste, Irena Katane	THEORETICAL AND LEGAL BASIS OF YOUNG PEOPLE'S MILITARY CAREER IN THE FIELD OF NATIONAL DEFENCE	288
	Viktorija Portere, Vladimirs Morevs	DIALOGUE IS A SIGN OF CONSTRUCTIVENESS IN MEDIATION	296

DEVELOPMENT OF WINTER WHEAT BLOTCHES DEPENDING ON FUNGICIDE TREATMENT SCHEMES AND NITROGEN RATES

*Agrita Švarta, Gunita Bimšteine, Zinta Gaile, Terēze Stanka, Linda Daugaviņa, Ieva Plūduma-Pauniņa

Latvia University of Life Sciences and Technologies, Latvia

*Corresponding author's email: agrita.svarta@llu.lv

Abstract

One of the factors affecting winter wheat grain yields are leaf blotches. The two-factorial trial was conducted in the Research and Study farm 'Pēterlauki' in 2017/2018 and 2018/2019 (Latvia). Four nitrogen rates and five fungicide treatment schemes were used. The aim was to clarify the impact of leaf blotches on the winter wheat yield. In winter wheat plots, the tan spot (caused by *Pyrenophora tritici-repentis*) dominated but also Septoria leaf blotch (caused by *Zymoseptoria tritici*) was found. The severity of leaf blotches in winter wheat was low in both years due to dry and warm weather. The development of leaf blotches was influenced by fungicide application schemes, but not by nitrogen fertilizer rate. The total disease impact during the vegetation period was estimated by calculation the area under the disease progress curve (AUDPC). AUDPC for both diseases were significantly higher in the variant without fungicides (F0) and in the variant, where half of dose of fungicides at the growth stage (GS) 55–59 (F1) was used. The using of full dose of fungicide at the GS 55–59 (F2) as well as using of fungicides two (F3) or three (F4) times in growing season significantly decreased the values of AUDPC for both diseases, but differences among AUDPC values in mentioned three variants were not significant. Results showed that the nitrogen fertilization significantly increased the average per both years grain yield until the nitrogen rate N180. Fungicide treatment schemes had no significant effect on the average grain yield.

Key words: *Pyrenophora tritici-repentis*, *Zymoseptoria tritici*, control, yield, values of AUDPC.

Introduction

The grain yield is influenced by the interaction of a number of factors such as cultivar, meteorological conditions and nitrogen fertilizers. Researches confirm that nitrogen fertilization significantly increased winter wheat grain yield, but increase of yield depends on the used rate of nitrogen (Litke, Gaile, & Ruža, 2017; Linina & Ruža, 2018).

An important factor affecting winter wheat grain yields is leaf blotches. In Latvia, the most widespread wheat leaf diseases are tan spot (caused by *Pyrenophora tritici-repentis*) and Septoria leaf blotch (caused by *Zymoseptoria tritici*) (Bankina *et al.*, 2014; Bankina *et al.*, 2018a).

The losses of winter wheat yield can range from 10–74% (Wegulo, Breathnach, & Baenziger, 2009; Wiik, 2009; Jevtić *et al.*, 2017; Bhatta *et al.*, 2018) and depend on development stage at which the infection occurs (Serrago *et al.*, 2011). The occurrence of diseases depends considerably on meteorological conditions (Wyczling, Lenc, & Sadowski, 2010; Bankina *et al.*, 2014; Jevtić *et al.*, 2017; Bankina *et al.*, 2018a), agrotechnical practices (Bankina *et al.*, 2018a) and fertilisation (Castro *et al.*, 2018).

The leaf blotches decrease green leaf area (Wyczling, Lenc, & Sadowski, 2010; Bhatta *et al.*, 2018), but the photosynthesis during grain filling period ensure dry matter accumulation in the grain, including nitrogen. The fungicide treatment strategies are aimed to protect leaves, particularly the flag leaf, and delay the senescence (Castro *et al.*, 2018). The yield benefits from fungicide application and not only depends on the amount of rainfall at all important growth stages for yield formation (Bhatta *et al.*, 2018),

but also on the frequency of the rainfall. Frequent rainfall provided conditions for continued pressure of tan spot and Septoria tritici blotches (Wyczling, Lenc, & Sadowski, 2010; Ronis & Semaškiene, 2011; Byamukama *et al.*, 2019).

The aim of this research was to clarify the impact of leaf blotches on the winter wheat yield under four nitrogen rates and five fungicide treatment schemes.

Materials and Methods

Two-factorial field trials were conducted at the Research and Study farm 'Pēterlauki' of Latvia University of Life Sciences and Technologies (56° 54.367' N and 23° 72.220') in the growing seasons of 2017/2018 and 2018/2019. Researched factors were: (A) five different fungicide treatment schemes (Table 1) and (B) four nitrogen fertilizer rates were used (N120(80+40), N150(80+70), N180(80+70+30) and N210(80+80+50). In total, twenty variants were arranged in four replications.

The winter wheat cultivar 'Skagen' was used in the trial. This cultivar is characterized by good productivity and winterhardiness. Sowing rate depended on sowing time and trial meteorological conditions: 450 germinable seeds m⁻² in 2017/2018 and 500 germinable seeds m⁻² in 2018/2019. In 2018, wheat sowing was delayed to the end of September due to adverse weather conditions, and in this case, sowing rate was increased a little.

The soil at the site was loamy, stagnogley. The soil is characterized by the following indicators depending on the year: pH KCL = 6.4–7.0, organic matter content 29–42 g kg⁻¹, P₂O₅ content 118–138 mg kg⁻¹ and K₂O content 208–262 mg kg⁻¹ of the soil.

Table 1

The fungicide treatment schemes

Variant	Used fungicides		Treatment timing – growth stage (GS) according BBCH*
	active ingredients of fungicides	dose, L ha ⁻¹	
F0	Without fungicides	–	–
F1 (one treatment)	Prothioconazole 130 g L ⁻¹ ; bixafen 65 g L ⁻¹ ; fluopyram 65 g L ⁻¹	0.750	55–59
F2 (one treatment)	Prothioconazole 130 g L ⁻¹ ; bixafen 65 g L ⁻¹ ; fluopyram 65 g L ⁻¹	1.500	55–59
F3 (two treatments)	Prothioconazole 160 g L ⁻¹ ; spiroxamin 300 g L ⁻¹	0.625	32–33
	Prothioconazole 130 g L ⁻¹ ; bixafen 65 g L ⁻¹ ; fluopyram 65 g L ⁻¹	0.750	55–59
F4 (three treatments)	Prothioconazole 160 g L ⁻¹ ; spiroxamin 300 g L ⁻¹	0.625	32–33
	Prothioconazole 130 g L ⁻¹ ; bixafen 65 g L ⁻¹ ; fluopyram 65 g L ⁻¹	0.750	55–59
	Metconazole 90 g L ⁻¹	1.000	63–65

*BBCH – the phenological growth stages of cereals according to the ‘Biologische Bundesanstalt, Bundessortenamt und Chemische Industrie’ (BBCSH) scale.

Before sowing, fertilizer was applied N – 25 kg ha⁻¹, P₂O₅ – 65 kg ha⁻¹, K₂O – 65 kg ha⁻¹. Weeds were controlled using herbicides in both years: in 2018, granstar premia 50 SX (methyl-tribenuron 500 g kg⁻¹) 22 g ha⁻¹ + Primus (florasulam 50 g L⁻¹) 0.1 L ha⁻¹ at 07.05.2018., in 2019, biathlon 4D (tritosulfuron 714 g kg⁻¹; florasulam 54 g kg⁻¹) + adjuvant Dash 0.5 L ha⁻¹ in were used. In spring, after the vegetation renewing, nitrogen fertilizer (NH₄NO₃; N 34.4%) was applied for all investigated variants. The second top-dressing was done at GS 29–31 using ammonium sulphate ((NH₄)₂SO₄; N 21%, S 24%) at the rate 100 kg ha⁻¹. The remaining amount of needed nitrogen was added using ammonium nitrate (NH₄NO₃; N 34.4%). The third top-dressing was done at GS 47–51 with ammonium nitrate. The rate of nitrogen was divided into two applications for variants N120 and N150, and into three applications – for variants N180 and N210.

After harvesting, grain was weighed, grain purity and moisture content detected and yield data were recalculated to standard moisture (14%) and 100% purity.

The incidence and severity of the disease were evaluated for the whole plant at the growth stage (GS) of the beginning of stem elongation (GS31), for the 3 upper leaves at the stages ‘Flag leaf just visible’ till ‘flag leaf stage: flag leaf fully unrolled, ligule just visible’ (GS 37–39) and the full flowering (GS

63–65), for the 2 upper leaves – at the stage of early milk (GS 73) and at the stage of late milk (GS 75–79). Growth stages were noted according to BBCH scale. In the first assessment, 50 plants were evaluated. In further assessments, 50 leaves were evaluated from every plot, proportionally taking the flag leaves, the first leaves and the second leaves. The total disease impact during the vegetation period was estimated by calculating the area under the disease progress curve (AUDPC).

For data statistical processing the analysis of variance was used. R-Studio for data processing was used. Bonferroni test was used for the comparison of means, the differences were considered statistically significant when p < 0.05. Significantly different means were labelled with different letters in superscript (a, b). The relationship between the winter wheat yield and the development of leaf blotch was analyzed by correlation analyses.

The meteorological data were summarized according to growth stages when the evaluation of diseases was done (Table 2). The weather conditions slightly differed during the years of investigation. The air temperatures were higher than long-term observations in the both trial years. There was a significant difference between vegetation starting dates (respectively – on 3 April 2018 and on 15 March 2019). The time from the starting of vegetation till the stage of stem elongation was relatively short (34 days)

Table2

Meteorological conditions during the period of investigation

Year	Growth stages	Average temperature, °C	Amount of precipitation, mm	Number of rainy days (>2mm)
2018	31–39	16.2	4	1
	39–65	17.6	2	0
	65–73	17.9	0	0
	73–79	15.8	14	3
2019	31–39	13.3	14	1
	39–65	16.3	5.8	0
	65–73	20.5	1.6	0
	73–79	18.8	6.2	1

and with an increased amount of precipitation in April 2018, but in 2019, this period was 52 days long. There was no precipitation in April 2019. Lack of moisture at all important growth stages for yield formation was observed. Overall, the meteorological situation was unfavourable for the plant growth and development in both trial years.

Results and Discussion

The development of leaf blotches

In winter, wheat plots, the tan spot (caused by *Pyrenophora tritici-repentis*) dominated, but also Septoria leaf blotch (caused by *Zymoseptoria tritici*) was found. Differences in the development of leaf blotches in each trial year separately were described in previous publications (Bankina, Stanka, & Grickeviča, 2018b; Stanka, Bankina, & Daugaviņa, 2019).

The incidence and severity of leaf blotches in winter wheat was low in both years. Dry and warm weather delayed the development of leaf blotches. It is known, that precipitation is necessary for the development of leaf blotches. Especially the causal

agent of Septoria leaf blotch requires a moist leaf surface for successful infection. The pathogen spread throughout the crop canopy via rain splash originating (Castro *et al.*, 2018).

The tan spot progression during the vegetation period is shown in Figure 1. The first symptoms of tan spot were observed already at GS 31–32, but the development of disease was slow and similar till GS 71–73 in all fungicide treatment schemes. Rapid development of tan spot began at the time of ripening of grains. The highest severity of tan spot (10.4%) was obtained in control variant where winter wheat was grown without the application of fungicides. With the application of fungicides, the severity of tan spot decreased until 3.6–6.1%.

Septoria leaf blotch started later, the first symptoms were observed only at the flag leaf stage (GS 37–39). Overall, the progression of Septoria leaf blotch was slower than that of tan spot (Figure 2). The highest severity of Septoria leaf blotch (3.7%) was obtained in control variant where winter wheat was grown without the application of fungicides. The application

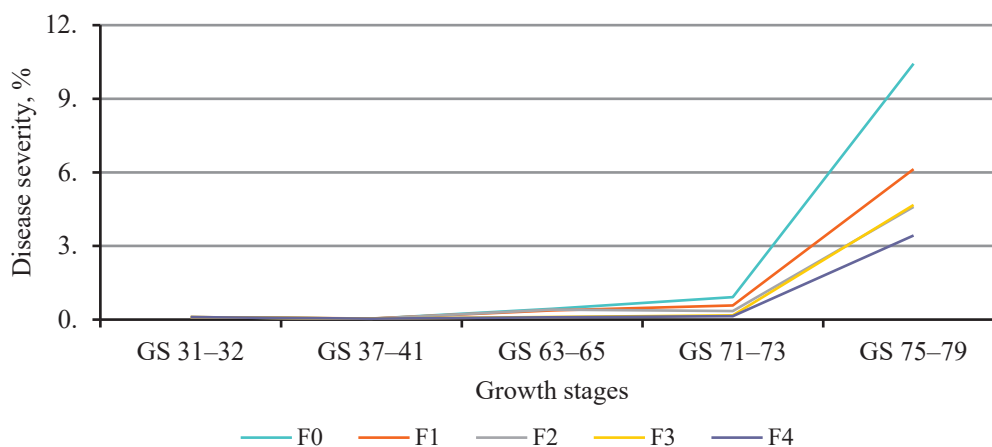


Figure 1. Development of tan spot depending of fungicide treatment schemes (average data per 2017/2018–2018/2019).

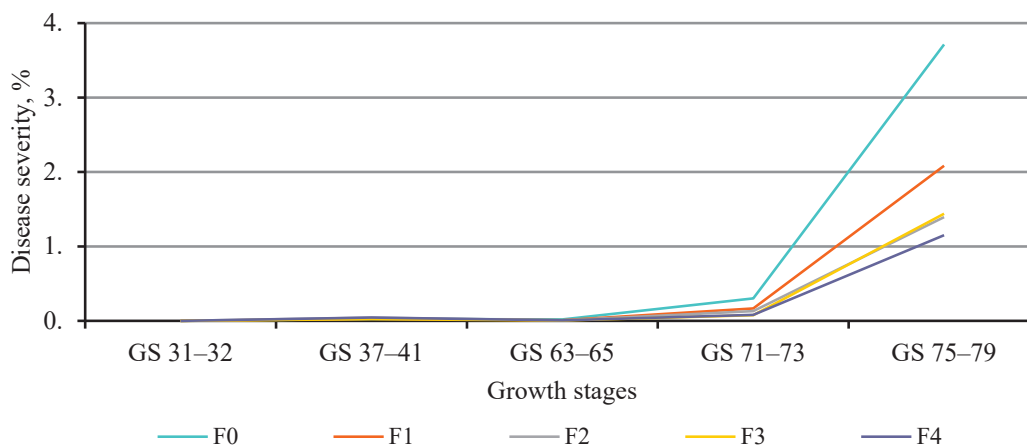


Figure 2. Development of Septoria leaf blotch depending on fungicide treatment schemes (average data per 2017/2018–2018/2019).

of fungicides decreased the severity of Septoria leaf blotch until 1.2–2.1%.

The total impact of diseases during the vegetation period depending on fungicide treatment scheme is shown by AUDPC (Figure 3). The development of leaf blotches was influenced by fungicide application schemes ($p < 0.001$ for both diseases), but not by nitrogen fertilizer rate ($p = 0.47$ for tan spot, $p = 0.97$ for Septoria leaf blotch). Some studies have reported that N fertilization may also affect distribution of foliar diseases. For example, in Argentina researchers found that only in the wettest years with more disease pressure, severity of Septoria leaf blotch and tan spot significantly decreased when the N rate increased, but in the dry years no differences were detected (tested variants – N0, N70 and N140 kg ha⁻¹) (Castro *et al.*, 2018). In another research Fleitas *et al.* (2018) found that, in untreated variants, the values of AUDPC for tan spot were lower with higher N rates.

Differences of AUDPC values for tan spot between variants of fungicide treatment schemes ranged between 24.4 and 77.4 units. Values of AUDPC were the highest in the control variant without fungicides (F0). The differences among the variants of different schemes were also significant. In variant F1, where half of dose of fungicides at the GS 55–59 was applied, the decrease of AUDPC units was not significant ($p = 0.06$) in comparison with control variant (F0). The significant decrease of the development of tan spot was obtained in variant with full dose of fungicide application at the GS 55–59 (F2) and in variants where winter wheat was treated with fungicides two (F3) or three (F4) times in the growing season. The differences of AUDPC values among these fungicide treatment schemes (F2, F3 and F4) were not significant.

The differences of AUDPC values for Septoria leaf blotch (Figure3) between variants of fungicide treatment schemes ranged between 8.4 and 26.0 units.

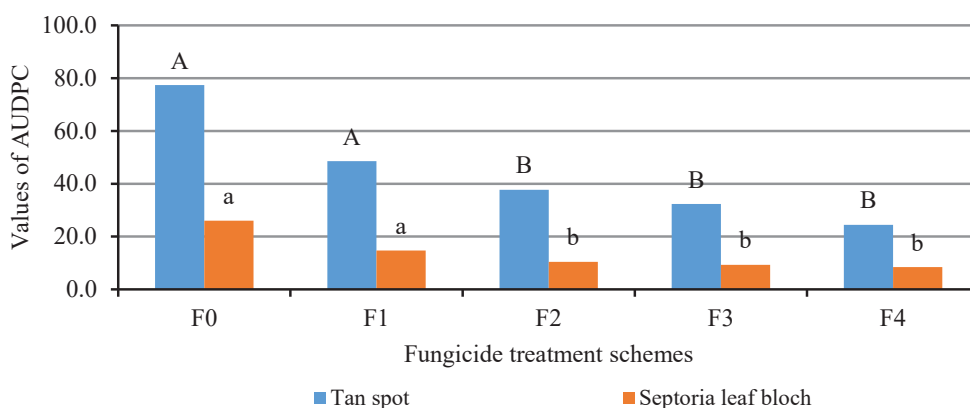


Figure 3. Values of areas under the disease progress curve (AUDPC) of leaf blotches depending on fungicide treatment schemes (average data 2017/2018–2018/2019).

Different letters denote significant differences:

A, B – for average values of AUDPC for tan spot;

a, b – for average values of AUDPC for Septoria leaf blotch.

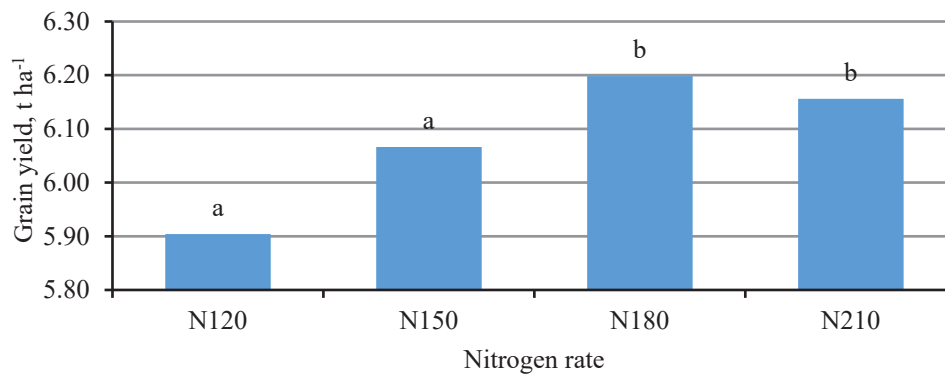


Figure 4. Winter wheat grain yield depending on the nitrogen rate (average data, 2017/2018–2018/2019). Different letters denote significant differences: ^{a, b} – for average yields of two trial years.

The influence of fungicide treatment schemes on the development of Septoria leaf blotch was similar to that of tan spot.

The results of researches about effectivity of various fungicide treatment schemes in different countries were contradictory. The researches showed that two fungicide applications are not necessary (Bankina *et al.*, 2014), but Wyczling, Lenc & Sadowski (2010) obtained a better effect after two applications. The results from a research in Nebraska showed that the effect of fungicide application timing at the GS 31 (first node on the stem detectable) versus GS 39 (ligule/collar of flag leaf just visible) on the intensity of leaf blotches or on yield was not consistent. The best predictor of yield losses caused by leaf blotches is disease severity at flowering, and fungicides used at this time can prevent significant yield losses (Wegulo, Breathnach, & Baenziger, 2009).

Wheat yield

Both trial years were unfavourable for winter wheat yield formation; the average winter wheat yield per two trial years was 5.90–6.20 t ha⁻¹ depending on variants. A year as a factor significantly influenced wheat yield ($p < 0.001$). Lower yields (5.03–5.57 t ha⁻¹) were obtained in 2018/2019, when the meteorological conditions from sowing until harvesting were worse for high yield formation even if compared with 2017/2018 which also was not appropriate for high yield development. Other researchers also found that limited water availability significantly reduces grain yield (Racz *et al.*, 2015; Smutná, Elzner, & Středa, 2018; Hlaváčová *et al.*, 2018).

The results show that nitrogen fertilization significantly increased the average grain yield per both years ($p < 0.001$). The influence of nitrogen rate differed during trial years ($p < 0.05$). In 2018, a significant yield increase was observed at the nitrogen fertilizer rate N210 but in 2019 – even at N180. It coincides with other studies which demonstrated that nitrogen application significantly increases the grain yield (Litke, Gaile, & Ruža, 2017). Assessing

the average two-year yield (Figure 4) depending on nitrogen rate, a significant increase of yield was obtained at the rate N180. Further increase of nitrogen rate did not cause a significant increase if compared with N180.

In 2018, when the average wheat yield was higher (6.33–7.33 t ha⁻¹), a significant distinction was found between variants in which different fungicide treatment schemes were applied, and higher yield on average was gained in the variants without fungicide treatment and in the variant with reduced fungicide dose at GS 55–59. It could be explained by stress for the plants due to the usage of fungicides, drought and hot weather. Fungicides may have negative effects on crop physiology, especially on photosynthesis, resulting in a decrease in both growth and yield of crop plants (Petit *et al.*, 2012). The researchers from Canada reported that using fungicides under dry conditions decreased the yield. Wheat were more resistant to drought than other tested crops, the application of fungicides one time in a growing period (flag leaf was fully emerged) only stressed plants. As a result, the grain yield was similar to non-treated variant although in years with normal amount of precipitation the use of fungicide increased grain yield by 5.2–15.0% (Kutcher *et al.*, 2011).

In 2019, the fungicide treatment did not significantly affect the wheat yield. Assessing the average two-year yield (Figure 5) depending on fungicide treatment schemes, significant differences were not found. Bhatta *et al.* (2018) found that efficacy of the foliar fungicide to improve grain yield largely depends on the meteorological conditions and the level of disease severity. In investigations the severity of leaf blotches was low. The results of a research in Poland (Wyczling, Lenc, & Sadowski, 2010) show that rainfall in the later part of the winter wheat growing season influenced the yield response to fungicide application, but the amount of precipitations in both years of our trial was very low. It is also known, that susceptible cultivars had a larger response

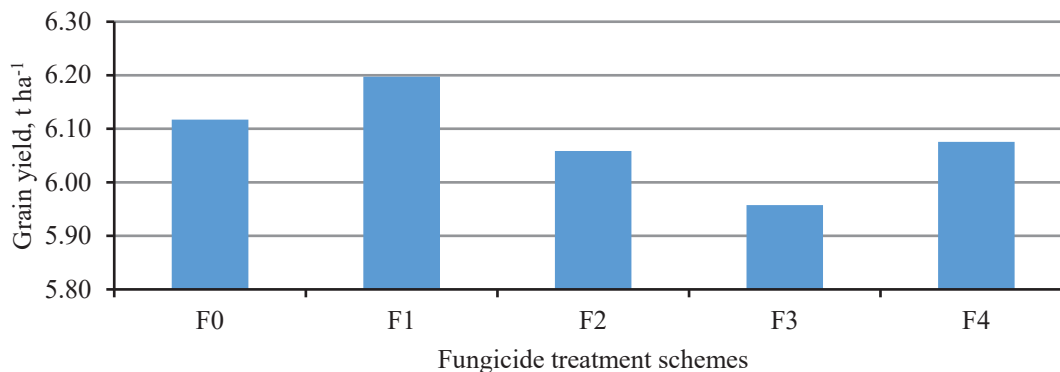


Figure 5. Winter wheat grain yield depending on fungicide treatment schemes (average data, 2017/2018–2018/2019).

to fungicides than resistant cultivars (Byamukama *et al.*, 2018; Bhatta *et al.*, 2018). Cultivar ‘Skagen’ used in our trials is characterised as comparatively resistant against diseases.

Leaf blotch disease’s severity on upper three leaves at GS 55 and upper two leaves at GS 75 significantly negatively correlated with the yield level. Wegulo, Breathnach, & Baenziger (2009) found that severity of leaf blotches at GS 60 had the strongest relationship to yield. Jevtić *et al.* (2017) found that the strongest relationship between values of AUDPC of Septoria leaf blotch and yield includes the period from the end of flowering (GS 69) to milk stage (GS 70–73). In our investigations, the severity of leaf blotches was low at this time and only a weak correlation ($r = 0.39$, $p < 0.001$) in 2018 between the total sum of AUDPC of tan spot and the yield was observed, but in 2019 – was not observed. A correlation between the total sum of AUDPC of Septoria leaf blotch and the yield was not observed.

Conclusions

The severity of leaf blotches in winter wheat was low in both years due to the dry and hot weather and did not influence the winter wheat grain yield significantly. Nitrogen fertilization increased the winter wheat grain

yield, but did not have a significant effect on the development of leaf blotches. A significant average yield increase was obtained till the nitrogen rate of N180, further increase of nitrogen rate did not cause a significant increase of yield.

Fungicide treatment schemes had no significant effect on the average grain yield but decreased the development of leaf blotches significantly. The using of full dose of fungicide at the GS 55–59 as well as using fungicides two or three times in the growing season significantly decreased the values of AUDPC for both diseases, but differences among AUDPC values in the three mentioned variants were not significant.

There was an untypically low amount of precipitation in both trial years and further studies are necessary to investigate different meteorological conditions and various levels of leaf blotch development.

Acknowledgements

The research was supported by the EIP-AGRI project ‘The development of the decision-making support system for restriction of the diseases, affecting leaves and ears of winter wheat’.

References

- Bankina, B., Gaile, Z., Balodis, O., Bimšteine, G., Katamadze, M., Kreita, Dz., Paura, L., & Priekule, I. (2014). Harmful winter wheat diseases and possibilities for their integrated control in Latvia. *Acta Agriculturae Scandinavica, Section B – Soil & Plant Science*, 64(7), 615–622. DOI: 10.1080/09064710.2014.949296.
- Bankina, B., Bimšteine, G., Arhipova, I., Kaņeps, J., & Stanka, T. (2018a). Importance of agronomic practice on the control of winter wheat diseases. *Agriculture*, 8, 56. DOI: 10.3390/agriculture8070056.
- Bankina, B., Stanka, T., & Grickeviča, K. (2018b). Kviešu lapu attīstība atkarībā no fungicīdu smidzināšanas shēmas (Development of wheat leaf diseases depending on fungicide application schemes). No Ražas svētki ‘Vecauce – 2018’: Latvijas – 100, Lauksaimniecības izglītībai – 155. Zinātniskā semināra (2018. g. 1. novembris) rakstu krājums (13.–16. lpp.). Vecauce, Latvija. (in Latvian with English abstract).
- Bhatta, M., Regassa, T., Wegulo, S., & Baenziger, P.S. (2018). Foliar fungicide effects on disease severity, yield and agronomic characteristics of modern winter wheat genotypes. *Agronomy Journal*, 110 (2), 1–9. DOI: 10.2134/agronj2017.07.0383.

- Byamukama, E., Ali, S., Kleinjan, J., Yabwalo, D.N., Graham, C., Caffè-Treml, M., Mueller, N.D., Rickertsen, J., & Berzonsky, W.A. (2019). Winter wheat grain yield response to fungicide application is influenced by cultivar and rainfall. *The Plant Pathology Journal*, 35(1), 63–70. DOI: 10.5423/ORJ.OA.2018.0056.
- Castro, M.K., Fleitas, M.C., Scierenbeck, M., Gerard, G.S., & Simón, M.R. (2018). Evaluation of different fungicides and nitrogen rates on grain yield and bread-making quality in wheat affected by *Septoria tritici* blotch and yellow spot. *Journal of Cereal Science*, 83, 49–57. DOI: 10.1016/j.jcs.2018.07.014.
- Fleitas, M.C., Scierenbeck, M., Gerard, G.S., Dietz, J.I., Golik, S.I., & Simón, M.R. (2018). Breadmaking quality and yield response to the green leaf area duration caused by fluxapyroxad under three nitrogen rates in wheat affected with tan spot. *Crop Protection*, 106, 201–2019. DOI: 10.1016/j.cropro.2018.01.004.
- Hlaváčová, M., Klem, K., Rapantová, B., Novotná, K., Urban, O., Hlavinka, P., ... Trnka, M. (2018). Interactive effects of high temperature and drought stress during stem elongation, anthesis and early grain filling on the yield formation and photosynthesis of winter wheat. *Field Crop Research*, 221, 182–195. DOI: 10.1016/j.fcr.2018.02.022.
- Jevtić, R., Župunski, V., Lalošević, M., & Župunski, L. (2017). Predicting potential winter wheat losses caused by multiple disease systems and climatic conditions. *Crop Protection*, 99, 17–25. DOI: 10.1016/j.cropro.2017.05.005.
- Kutcher, H.R., Johnston, A.M., Bailey, K.L., & Malhi, S.S. (2011). Managing crop losses from plant diseases with foliar fungicides, rotation and tillage on a Black Chernozem in Saskatchewan, Canada. *Field Crops Research*, 124, 205–212. DOI: 10.1016/j.fcr.2011.05.018.
- Linija, A., & Ruža, A. (2018). The influence of cultivar, weather conditions and nitrogen fertilizer on winter wheat grain yield. *Agronomy Research*, 16(1), 147–156. DOI: 10.15159/AR.18.034.
- Litke, L., Gaile, Z., & Ruža, A. (2017). Nitrogen fertilizer influence on winter wheat yield and yield components depending on soil tillage and forecrop. In 'Research for Rural Development 2017' 23rd Annual International Scientific Conference Proceedings, 17–19 May 2017 (pp. 54–61). Jelgava: LLU. DOI: 10.22616/rrd.23.2017.049.
- Petit, A.N., Fontaine, F., Vatsa, P., Clément, C., Vaillant-Gaveau, N. (2012). Fungicide impacts on photosynthesis in crop plants. *Photosynthesis Research*, 111, 315–326. DOI: 10.1007/s11120-012-9719-8
- Racz, I., Kadar, R., Moldovan, V., & Haş, I. (2015). Performance and stability of grain yield and yield components in some winter wheat varieties. *Romanian Agricultural Research*, 32, 11–18.
- Ronis, A., & Semaškiene, R. (2011). Relationship of AUDPC values of tan spot and *Stagonospora glume* blotch with grain infection in winter and spring wheat. *Zemdirbyste = Agriculture*, 98(1), 11–18.
- Serrago, R.A., Carretero, R., Bancal, M.O., & Miralles, D.J. (2011). Grain weight response to foliar diseases control in wheat (*Triticum aestivum* L.). *Field Crops Research*, 120, 352–359. DOI: 10.1016/j.fcr.2010.11.004
- Smutná, P., Elzner P., & Středa T. (2018). The effect of water deficit on yield and yield component variation in winter wheat. *Agriculturae Conspectus Scientificus*, 82(1), 105–111.
- Stanka, T., Bankina, B., & Daugaviņa, L. (2019). Kviešu lapu plankumainību ierobežošanas efektivitāte atkarībā no fungicīdu smidzināšanas shēmas (Control efficiency of wheat leaf blotches depending on fungicide application schemes). In Ražas svētki 'Vecauce – 2019': Gaidot starptautisko zinātnes izvērtējumu. Zinātniskā semināra (2019. g. 7. novembris) rakstu krājums (45.–48. lpp.). Vecauce, Latvija. (in Latvian with English abstract).
- Wegulo, S.N., Breathnach, J.A., & Baenziger, P.S. (2009). Effect of growth stage on the relationship between tan spot and spot blotch severity and yield in winter wheat. *Crop Protection*, 28, 696–702. DOI: 10.1016/j.cropro.2009.04.003.
- Wiik, L. (2009). Yield and disease control in winter wheat in southern Sweden during 1977–2005. *Crop Protection*, 28, 82–89. DOI: 10.1016/j.cropro.2008.09.002.
- Wyczing, D., Lenc, L., & Sadowski, C. (2010). Comparison of disease occurrence and green leaf area (GLA) of winter wheat depending on the forecrop and differentiated fungicidal protection used. *Journal of Plant Protection Research*, 50(4), 489–495. DOI: 10.2478/v10045-010-0081-6.

THE EFFECT OF CROP ROTATION AND SOIL TILLAGE ON WINTER WHEAT YIELD

*Madara Darguza, Zinta Gaile

Latvia University of Life Sciences and Technologies, Latvia

*Corresponding author's email: madara.darguza@llu.lv

Abstract

Wheat (*Triticum*) is one of the three most important field crops used for food in the world, as well as in Latvia. The two-factorial trial was conducted at the Research and Study farm 'Pēterlauki', Latvia, with the aim to find out the effect of soil tillage and crop rotation on winter wheat grain yield formation. Two soil tillage systems (conventional and reduced), and three crop rotations with different winter wheat (*Triticum aestivum*) proportion in it (100, 67 and 25%) and different fore-crops (wheat, oilseed rape (*Brassica napus* ssp. *oleifera*), faba bean (*Vicia faba*)) were used. Long-term trial was started in 2009, however, the data from 2016/2017, 2017/2018 and 2018/2019 growing seasons was used for this report. The highest average wheat yield was harvested in 2017 (7.17 t ha⁻¹), and it was significantly ($p < 0.001$) higher than yields in 2018 and 2019 (on average 6.18 t ha⁻¹ and 5.68 t ha⁻¹, respectively). Crop rotation with winter wheat proportion 25%, in which faba bean was wheat fore-crop, showed the highest average grain yield (7.35 t ha⁻¹), but the lowest yield was obtained in rotation with 100% wheat proportion (on average 5.52 t ha⁻¹). Crop rotation scheme had a significant influence on the yield ($p < 0.001$) and 1000 grain weight ($p < 0.001$). Fore-crop influenced the yield ($p < 0.001$), number of spikes per 1 m² ($p < 0.001$), and number of grain per spike ($p = 0.008$) significantly. Soil tillage did not affect the studied parameters importantly. Conditions of the trial year affected all parameters significantly.

Key words: wheat, yield formation, crop rotation, soil tillage.

Introduction

One of the most important field crops globally is wheat (*Triticum*), and it is ranked in the first place by harvested area in the world, and in the third place by total grain production from cereals (after rice (*Oryza sativa*) and maize (*Zea mays*)) in 2018 by the latest data from Food and Agriculture Organization of United Nations (FAOSTAT data, 2020 March, available at: <http://www.fao.org/faostat/en/#data/QC>). Wheat grain is widely used for food consumption, and it is necessary to harvest high enough grain yield to feed the growing number of world population. Grain yield and its formation (values of yield components) depend directly on the growing conditions of wheat; growing conditions can be improved agronomically by choosing an appropriate soil tillage system and using thoughtful crop rotation, which also regulates soil moisture and helps to limit harmful organisms.

Crop diversification is adjusted to economic outcome, and it is affected by agricultural policy (Babulicová, 2016). Wheat yield level is at risk to decrease, while wheat is grown in rotation with a large proportion of wheat (Bonciarelli *et al.*, 2016). The increase of wheat yield had been found in crop rotations if pulses (Babulicová, 2016), oilseeds (Schillinger & Paulitz, 2018) or root crops (Smagacz, Kozieł, & Martyniuk, 2016) are wheat fore-crops in the rotation. Changing the sequence of crops grown on arable land is an opportunity to increase wheat yields, and it was claimed that this increase may be up to 20% (Kirkegaard *et al.*, 2008). Usage of well-planned crop rotation with no repeated wheat in rotation may limit wheat leaf diseases (Mazzilli *et al.*, 2016).

Conventional soil tillage helps to limit weeds in field (Gozubuyuk *et al.*, 2015) and wheat leaf diseases, like tan spot (caused by *Pyrenophora tritici-repentis*) (Cotuna *et al.*, 2015). Conventional tillage, also named as traditional, which characterizes with comparatively deep (up to 22–30 cm) soil mould-board ploughing, is often used as soil tillage system (Rieger *et al.*, 2008; Jug *et al.*, 2011; Gozubuyuk *et al.*, 2015; Hiel *et al.*, 2018). The effect of different soil tillage systems (conventional (traditional) or reduced to varying degrees) on wheat yield was contradictory (e.g. Arvidsson, 2010; Schlegel *et al.*, 2017) and therefore further research is needed in different environmental conditions.

M. Babulicova (2016) studied the impact of crop rotation and fore-crop (field pea (*Pisum sativum*), and barley (*Hordeum vulgare*)) on grain yield in Slovakia and found fore-crop influence on winter wheat grain yield and 1000 grain weight (TGW). Values of both were higher when field pea was used as a fore-crop. It is important to know that the diversification of crops in rotation and used soil tillage system influence not only the grain yield, but also its forming components – the number of spikes per 1m², number of grain per spike and TGW.

The aim of this paper was to evaluate the influence of soil tillage system and crop diversification in crop rotation on the winter wheat grain yield and its components' formation. The yield and grain quality data depending on investigated factors from two previous trial years (2016/2017 and 2018/2019) have been reported in the paper by M. Darguza & Z. Gaile (2019). In this paper, the yield and TGW data is supplemented with the third year data, and other yield components are also analysed.

Table 1

**Growing sequence of crops included in rotation (2) oilseed rape–wheat–wheat, and
(3) faba bean–wheat–oilseed rape–barley in described trial years 2017 – 2019**

Crop rotation	Plot No.	Crop in 2016	Crops harvested in season		
			2017	2018	2019
OR–W–W	1 st	w. oilseed rape	w. wheat	w. wheat	w. oilseed rape
	2 nd	w. wheat	w. oilseed rape	w. wheat	w. wheat
FB–W–OR–B	1 st	s. faba bean	w. wheat	w. oilseed rape	s. barley
	2 nd	w. oilseed rape	s. barley	s. faba bean	w. wheat
	3 rd	w. wheat	w. oilseed rape	s. barley	s. faba bean

w. or s. is added before crop species to identify the type of crop: w – winter or s – spring

Materials and Methods

The long-term trial was started at the Research and Study farm ‘Peterlauki’ (56° 30.658’ N and 23° 41.580’ E) of Latvia University of Life Sciences and Technologies in 2009. Data analysed in this paper is from three seasons (2016/2017, 2017/2018 and 2018/2019). The trial is two-factorial: the effect of soil tillage system and crop rotation were studied. Two soil tillage systems were applied for each crop rotation: a conventional system (CT) with mould-board ploughing at a depth of 22–24 cm and reduced system (RT), where the disc harrowing at a depth to 10 cm was used. Three different variants of crop rotation were examined: rotation (1) repeated winter wheat (*Triticum aestivum*) sowings (W–W; wheat 100%), rotation (2) oilseed rape (*Brassica napus* ssp. *oleifera*) – wheat – wheat (OR–W–W; wheat 67%), rotation (3) faba bean – wheat – oilseed rape – spring barley (FB–W–OR–B; wheat 25%). The field trial was arranged in a two-factorial split-plot design in two blocks. Each plot in every block was split in half, thus forming four replications.

Winter wheat fore-crop, as well as harvested crop in rotation (1) was always winter wheat, as it was rotation with repeated winter wheat sowings (wheat 100%). In rotations (2) and (3), fore-crops and harvested crops (Table 1) varied from year to year. Only winter wheat yield is analysed in this paper.

Winter wheat variety used in 2016/2017 was ‘Zentos’, but ‘Skagen’ was used in 2017/2018 and 2018/2019. The reason of variety change, as well as soil conditions on the site, were described in the paper by M. Darguza & Z. Gaile, 2019. Sowing time differed depending on meteorological conditions of the trial year (Table 2). In autumn of each sowing year, complex mineral fertilizers were used at the rate: 25 kg N ha⁻¹, 65 kg P₂O₅ ha⁻¹ every year, but with different K₂O rates: 40 kg K₂O ha⁻¹ was given in 2016/2017, but 65 kg K₂O ha⁻¹ – in 2017/2018 and 2018/2019; in addition, fertilizer contained 5 kg S ha⁻¹ in 2016/2017. Nitrogen top-dressing rate in spring was as follows: 172 kg N ha⁻¹ in 2017, and 155 kg ha⁻¹

in 2018 and 2019; the total rate was divided into two applications (at the renewal of vegetation 86 kg N ha⁻¹, and 69–86 kg N ha⁻¹ at the GS 31–32). Control of harmful organisms in trial plots was done according to integrated cropping system, and it differed between trial years. Control was based on field monitoring data: each year the weed control was done in the spring season (Mustang Forte (10 g L⁻¹, aminopyralid, 5 g L⁻¹, florasulam, 180 g L⁻¹ 2.4-D) 0.8 L ha⁻¹ in the spring 2017 and 2018, Tombo WG (50 g kg⁻¹ pyroxulam, 25 g kg⁻¹ florasulam, 50 g kg⁻¹ aminopyralid) 200 g ha⁻¹ + Dash 0.5 L ha⁻¹ in 2019), the disease control by using fungicides Adexar (62.5 g L⁻¹ epoxiconazole; 62.5 g L⁻¹ fluxapyroxad) 1 L ha⁻¹ in 2017 and 2 L ha⁻¹ in 2018, Opera N (85 g L⁻¹ pyraclostrobin, 62.5 g L⁻¹ epoxiconazole) 1 L ha⁻¹ in 2019 at GS 39–51; insecticide was used only in 2018 (Fastac 50 (50 g L⁻¹ alpha-cypermethrin) 0.25 L ha⁻¹). Before winter wheat yield harvesting (at GS 87–89), sample sheets were taken for evaluation of yield components. Three sample sheets were taken from 0.125 m² from every variant in every replication (in total 12 sample sheets from one variant). The evaluated yield components were: **number of winter wheat spikes per 1m²** (counted from sample sheets and recalculated per 1 m²), **number of grains per spike** (grain was threshed from spikes in sample-sheets, then counted using equipment Contador (Pfeiffer), and divided by the number of spikes per sample sheet), **winter wheat TGW** (g) was detected from harvested yield by standard method (LVS EN ISO 520:2011).

Winter wheat grain yield was harvested (see dates in Table 2) by combine (Sampo 130 (Sampo Rosenlew)) and weighted; grain purity and moisture content was detected, and then harvested yield was converted to yield with 100% purity and 14% moisture content.

Mathematical calculations of data were performed by using RStudio Multi-way Anova analysis and correlation analysis. Also, a trial year effect on winter wheat grain yield and yield components were evaluated. Bonferroni test was used to detect the significance of differences.

Table 2

Winter wheat sowing and harvesting time, and vegetation renewal date in spring during trial years

Indicators	2016/2017	2017/2018	2018/2019
Sowing time	September 19 th	September 28 th	September 6 th
Start of vegetation period	April 14 th	April 7 th	March 15 th
Harvesting time	August 8 th	July 24 th	July 29 th

Table 3

Average air temperature and precipitation in trial place per trial period (2016/2017–2018/2019) and in comparison to long-term observations

Month	Temperature, °C				Precipitation, mm			
	2016/ 2017	2017/ 2018	2018/ 2019	long-term observation	2016/ 2017	2017/ 2018	2018/ 2019	long-term observation
Sowing year								
September	13.7	13.0	14.9	11.5	3.9	26.6	25.5	20.9
October	5.2	8.0	8.5	6.7	18.7	26.7	10.6	19.3
November	1.1	3.9	3.0	1.8	11.5	15.1	6.8	17.6
Harvesting year								
March	3.2	-1.8	3.0	-1.5	30.6	10.8	29.6	31.3
April	4.8	9.0	8.1	5.3	38.5	47.2	8.1	40.0
May	11.5	16.1	12.3	11.7	23.5	20.8	20.4	51.4
June	15.1	16.8	19.4	15.4	49.5	15.2	8.6	75.3
July	16.6	20.8	16.8	16.6	83.0	33.6	101.0	81.7
August	16.8	19.4	17.6	16.2	31.0	28.4	37.8	73.7

Meteorological data in trial years differed considerably according to the precipitation and temperature (Table 3). Meteorological situation favoured high winter wheat grain yield formation in 2017, but adverse conditions for winter wheat growth and development were observed in 2018 and 2019.

The season 2016/2017 started with warm weather and low precipitation in September and continued with optimal growing temperatures for plants, which was close to indicators of long-term observations, but the total amount of precipitation in spring season was lower, if compared to long-term observations. Season 2017/2018 differed from others with the highest amount of precipitation in autumn period, which was the reason of delayed sowing time (Table 3), and it had an impact on growing and development of wheat till the end of vegetation. In spring 2018, air temperature was higher than long-term average observations and it continued to be higher till harvesting, which led to shortening of vegetation period and faster ripening of grain. The amount of precipitation from May till harvesting was low. Plants suffered from lack of moisture at important growth stages (like tillering, spike formation and grain filling), and it influenced yield formation and decreased yield. The third trial

season 2018/2019 continued with lack of moisture during sowing, and wheat germination started only three weeks after sowing, when precipitation was observed; rain made soil crust and it led to lowered field germination. In the spring 2019, vegetation season started early – in the middle of March (Table 3); however, lack of moisture was still observed in soil, since low precipitation was observed even during the winter. Precipitation was low also in April, May and June 2019, when important yield components formed. Drought decreased winter wheat yield.

Results and Discussion

Winter wheat grain yield was significantly ($p < 0.001$) affected by crop rotation, fore-crop and year conditions. The highest average grain yield was harvested from rotation (3) FB–W–OR–B (7.35 t ha^{-1}), but the lowest – from rotation (1) W–W (5.52 t ha^{-1}) (Figure 1). Significant yield difference at 95% probability level was not found ($p = 0.47$), whether the fore-crop was oilseed rape (6.98 t ha^{-1}) or faba bean (7.35 t ha^{-1}). Used soil tillage treatment did not affect average wheat grain yield per trial period significantly ($p = 0.277$). Significant differences ($p < 0.001$) of wheat yields were observed depending

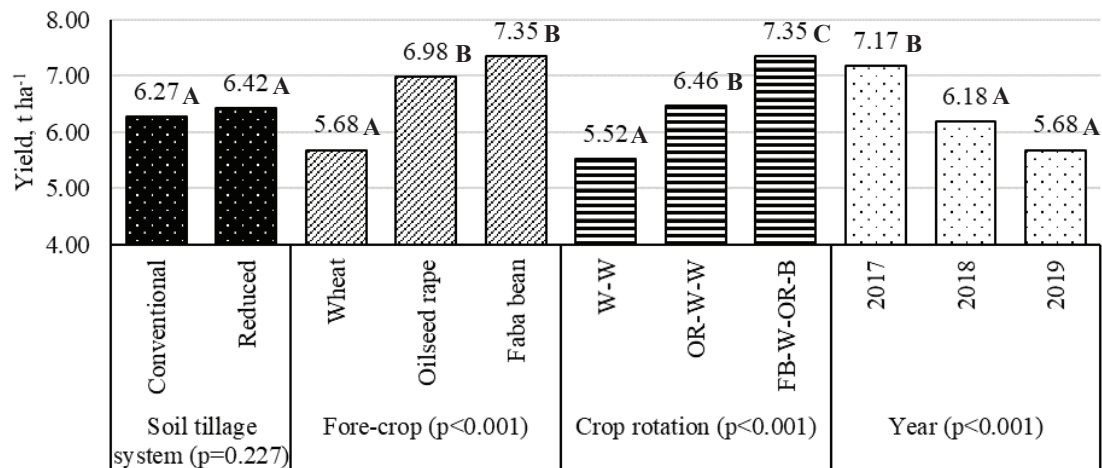


Figure 1. The grain yield of winter wheat depending on researched factors, t ha⁻¹: W-W –wheat 100% in rotation; W-W-OR – wheat 67% in rotation; FB-W-OR-B – wheat 25% in rotation. Significantly different means for each factor are marked with different letters A, B, C.

on conditions in the trial year. The highest average grain yield (7.17 t ha⁻¹) was obtained in 2017, when the meteorological situation was most favourable for wheat yield formation if compared to two following crop years (2018, 2019).

A positive effect of fore-crop from *Leguminosae* family has been found by M. Babulicova, when wheat was grown after pea, and the obtained yield was higher, if compared to that obtained after cereal fore-crop (Babulicova, 2016). J.F. Angus *et al.* (2015) reported that non-cereal wheat fore-crop provided an increase in wheat grain yield, e.g., if oilseed rape was

grown before wheat, or even a higher yield increase has been found if fore-crops were grain legumes; the yield increase varied from 20% after oilseed rape to 60% increase after legumes. It is also claimed that if fore-crop was oilseed rape, there is a positive influence on the second year wheat yield.

Soil tillage system effect on wheat yield is small. Results did not show significant yield differences, when different soil tillage systems were compared in clay and clay loam soil in the United Kingdom (with different tillage depth from 200 mm and less) (Giannitsopoulos, Burgess, & Rickson, 2019). Our

Table 4

Number of winter wheat spikes per 1 m² depending on researched factors

Factors	Year (p<0.001)			Average
	2017	2018	2019	
Crop rotation (p=0.335)				
W-W	542 ^a	534 ^a	383 ^a	486 ^A
W-W-OR	547 ^a	528 ^a	372 ^a	494 ^A
FB-W-OR-B	586 ^a	-	451 ^a	519 ^A
Fore-crop (p<0.001)				
wheat	542 ^a	527 ^a	377 ^a	470 ^A
oilseed rape	547 ^a	537 ^a	-	541 ^B
faba bean	586 ^a	-	451 ^b	519 ^{AB}
Soil tillage system (p=0.824)				
conventional	549 ^a	556 ^a	391 ^a	499 ^A
reduced	567 ^a	504 ^a	413 ^a	495 ^A
Average depending on trial year	558 ^B	530 ^B	402 ^A	×

W-W – wheat 100% in rotation; W-W-OR – wheat 67% in rotation; FB-W-OR-B – wheat 25% in rotation. Significantly different means for each factor are marked with different letters in superscript: ^{A,B} – significant difference for average number of winter wheat spikes of three trial years and means on factor graduations; ^{a,b} – significant difference in specific trial year.

results were similar and also obtained in clay soil, and they also match with A.J. Schlegel *et al.* (2017), who reported that average winter wheat yield was higher in variants, where no-till and reduced tillage systems were used if compared to CT, but yields were not significantly different between variants, where different tillage systems were used in half of the trial years (Schlegel *et al.*, 2017). Reduced tillage system has proved its advantages under rainfed conditions if compared to the CT system to get higher wheat grain yields (Pittelkow *et al.*, 2015).

The winter wheat yield component 'number of spikes per 1 m²' was moderate on average per trial years 497 (402–558; Table 4), and it was significantly ($p < 0.001$) affected by fore-crop and the year. Crop rotation ($p = 0.335$) and soil tillage system ($p = 0.824$) did not affect this yield component significantly.

Higher number of spikes per 1 m² on average was obtained, when wheat was grown after faba bean or oilseed rape. When analysing the results of each year separately, significant differences in average number of spikes per 1 m² were not found, when the values of 2017 and 2018 were compared. In addition, fore-crop similarly to crop-rotation and soil tillage system also did not affect values of this yield component significantly in 2017 and 2018. Significant difference ($p < 0.020$) in number of spikes per 1 m² was found in 2019 between variants, where fore-crop was wheat (377) and faba bean (451); these results influenced the average values during three year trial period. The lowest average number of spikes per 1 m² was observed in 2019 (402) due to low field germination

and poor tillering caused by drought. The calculated average field germination of winter wheat was 64% in 2018/2019. Meteorological conditions during germination were characterised by a low amount of productive precipitation, and another obstructive factor was soil crust, which formed after the rain in clay soil. As drought continued in autumn, winter and even next spring (Table 3), tillering, which can increase the number of spikes per 1 m², was poor.

It was reported by Vyn *et al.* (1991) that the number of wheat spikes per 1 m² is higher if other than wheat crop is sown before wheat in crop rotation (Vyn, Sutton, & Raimbault, 1991). The number of spikes depending on different fore-crops has been studied also in the USA, and it was reported that significantly higher number of wheat spikes per 1 m² was found after oat-pea mixture if compared to the variant, where spring wheat was used as fore-crop; the lowest number of spikes per 1 m² was found, when wheat fore-crop was soybean (Anderson, 2008). A soil tillage impact on plant density was found in Croatia in chernosem; higher plant density was found in variants, where shallow tillage (till 15 cm depth) was used if compared with the traditional tillage system, also soil tillage and year interaction was found (Jug *et al.*, 2011).

Correlation analysis showed a moderate positive relation between the number of spikes per 1 m² and yield ($r = 0.543 > r_{0.05} = 0.234$, $n = 72$).

The number of grains per spike differed significantly depending on a trial year ($p < 0.001$) and fore-crop ($p = 0.008$), and it varied from 26.4 in 2017 to 34.1 in 2019 (Table 5).

Table 5

Number of grain per spike of winter wheat depending on researched factors

Factors	Year ($p < 0.001$)			Average
	2017	2018	2019	
Crop rotation ($p = 0.312$)				
W-W	25.3 ^a	31.7 ^a	33.6 ^a	30.2 ^A
W-W-OR	25.1 ^a	32.5 ^a	32.8 ^a	30.8 ^A
FB-W-OR-B	28.7 ^a	-	35.8 ^a	32.3 ^A
Fore-crop ($p = 0.008$)				
wheat	25.3 ^a	32.2 ^a	33.3 ^a	31.2 ^A
oilseed rape	25.1 ^a	32.3 ^a	-	28.7 ^B
faba bean	28.7 ^a	-	35.8 ^a	32.3 ^A
Soil tillage system ($p = 0.164$)				
conventional	26.3 ^a	30.6 ^a	37.9 ^b	31.6 ^A
reduced	26.4 ^a	33.9 ^b	30.3 ^a	30.2 ^A
Average depending on trial year	26.4 ^B	32.2 ^A	34.1 ^A	×

W-W – wheat 100% in rotation; W-W-OR – wheat 67% in rotation; FB-W-OR-B – wheat 25% in rotation. Significantly different means for each factor are marked with different letters in superscript: ^{A, B} – significant difference for number of gains per spike of winter wheat of three trial years and means on factor graduations; ^{a, b} – significant difference in specific trial year.

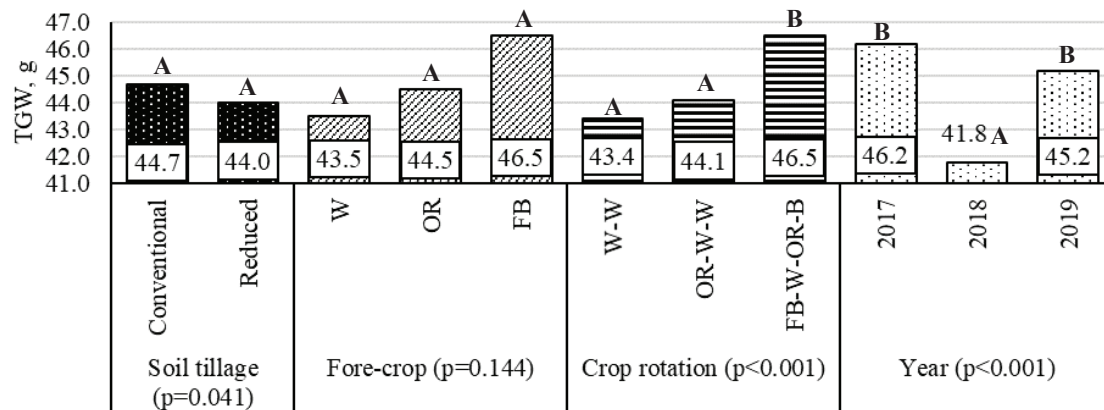


Figure 2. Winter wheat thousand grain weight (g) depending on researched factors: W–W – wheat 100% in rotation; W–W–OR – wheat 67% in rotation; FB–W–OR–B – wheat 25% in rotation. Significantly different thousand grain weight (g) means for each factor are marked with different letters: A, B.

The difference found in the average number of grain per spike depending on fore-crops, namely – when fore-crop was oil-seed rape – can be explained by data set; oilseed rape was fore-crop for wheat grown in 2017 and 2018, when the number of grain per spike on average was lower. Significantly lower ($p<0.001$) number of grain per spike was gained in 2017, when the highest number of spikes per 1 m^2 was observed and the highest grain yield was harvested. Correlation coefficient showed a moderate negative relation between the number of grain per spike and number of spikes per 1 m^2 ($r=-0.505 > r_{0.05}=0.234$, $n=72$) per three-year trial period, and in the season 2017/2018 ($r=-0.555 > r_{0.05}=0.404$, $n=24$) if calculation was done using data of each trial year separately. In R.L. Anderson's trials, a significant difference between the number of grain per spike depending on fore-crop (higher after soybean) was also found, and similarly the number of grain per spike was higher in cases with lower tiller density (Anderson, 2008), but significant difference in values of this parameter was not found, when fore-crops were maize and oilseed rape (Rieger *et al.*, 2008). Influence of soil tillage system on the number of grain per spike was not found also by other researchers, when traditional and reduced tillage systems were compared (Rieger *et al.*, 2008; Jug *et al.*, 2011).

TGW was significantly influenced by a crop rotation scheme ($p<0.001$) and trial year ($p<0.001$) (Figure 2). TGW has a dual nature – it is a yield component, as well as an indicator of grain quality. TGW in 2017 and 2018 was described in detail as an indicator of grain quality in our previous paper (Darguza & Gaile, 2019).

The average TGW of wheat grown in crop rotation (3) FB–W–OR–B was significantly higher (46.5 g) if compared with other two rotations. Mathematically

significant differences were not found between average TGW values depending on fore-crop in 2019; however, in years 2017 and 2018, it was found that in cases, when fore-crop was oil-seed rape or faba bean, winter wheat showed higher TGW. TGW was 3 g higher if wheat was grown after faba bean ($p<0.001$), and 1.6 g higher if fore-crop was oilseed rape ($p=0.424$) in comparison with the variant where wheat was fore-crop. The highest average TGW was noted in 2017 (46.2 g; Figure 2), when the weather conditions (namely amount of precipitation) during grain formation and filling were more favourable if compared with other two years. Similar results, when significantly higher TGW of wheat was obtained in the variant with pea as fore-crop if compared with barley as fore-crop have been found in Slovakia (Babulicova, 2016); similarly to our trial also significant differences of TGW values between trial years were noted. TGW differences between variants were not found if fore-crops were maize or oilseed rape (Rieger *et al.*, 2008). In our trial, a positive weak correlation was found between TGW and wheat yield ($r=0.405 > r_{0.05}=0.234$, $n=72$), when data of three years were used, and a positive moderate correlation between these two indicators was found also in specific trial years: in 2017 ($r=0.666 > r_{0.05}=0.404$, $n=24$) and in 2018 ($r=0.559 > r_{0.05}=0.404$, $n=24$). I.A. Cociu & E. Alionte (2011) reported that TGW very strongly correlated with grain yield.

Different soil tillage systems did not influence TGW (Figure 2), and similar results were found also by other researchers (Ozpinar, 2006; Cociu & Alionte, 2011; Jug *et al.*, 2011). S. Rieger *et al.* found that TGW did not differ between CT and minimal tillage variants, but it was mathematically lower in zero tillage variant (Rieger *et al.*, 2008).

Conclusions

Crop rotation scheme had a significant influence on yield and TGW, and the highest values of these parameters were obtained in four-crop rotation (faba bean – winter wheat – oil-seed rape – barley). Fore-crop affected yield and number of spikes per 1 m² significantly, and higher average values were obtained after oil-seed rape and faba beans as fore-crops; fore-crop affected also average per trial period number of grain per spike significantly, but interpretation of specific values of this parameter should be found

during next trial years. Soil tillage did not affect any of the studied parameters on average per three-year trial period significantly. All studied parameters were affected significantly by the conditions of trial years.

Acknowledgements

The study was financed by Ministry of Agriculture project ‘Influence of minimal soil tillage on its fertility maintenance, development and distribution of pests as well as crops’ yield and quality in resowings’ and LLU project Z33.

References

- Anderson, R.L. (2008). Growth and yield of winter wheat as affected by preceding crop and crop management. *Agronomy Journal*, 100, 977–980. DOI: 10.2134/agronj2007.0203.
- Angus, J.F., Kirkegaard, J.A., Hunt, J.R., Ryan, M.H., Ohlander, L., & Peoples, M.B. (2015). Break crops and rotations for wheat. *Crop and Pasture Science*, 66(6), 523–552. DOI: 10.1071/CP14252.
- Arvidsson, J. (2010). Energy use efficiency in different tillage systems for winter wheat on a clay and silt loam in Sweden. *European Journal of Agronomy*, 33(3), 250–256. DOI: 10.1016/J.EJA.2010.06.003.
- Babulicová, M. (2016). Enhancing of winter wheat productivity by the introduction of field pea into crop rotation. *Agriculture*, 62(2), 101–110. DOI: 10.1515/agri-2016-0011.
- Bonciarelli, U., Onofri, A., Benincasa, P., Farneselli, M., Guiducci, M., Pannacci, E., Tosti, G., & Tei, F. (2016). Long-term evaluation of productivity, stability and sustainability for cropping systems in Mediterranean rainfed conditions. *European Journal of Agronomy*, 77, 146–155. DOI: 10.1016/j.eja.2016.02.006.
- Cociu, A.I., & Alionte, E. (2011). Yield and some quality traits of winter wheat, maize, and soybean, grown in different tillage and deep loosening systems aimed to soil conservation. *Romania Agricultural Research*, 28, 109–120.
- Cotuna, O., Paraschivu, M., Paraschivu, A., & Saratelanu, V. (2015). The influence of tillage, crop rotation and residue management on tan spot (*Drechslera Tritici Repentis* Died. Shoemaker) in winter wheat. *Research Journal of Agricultural Science*, 47(2), 13–21.
- Darguza, M., & Gaile, Z. (2019). Yield and quality of winter wheat, depending on crop rotation and soil tillage. In Annual 25th International Scientific Conference ‘Research for Rural Development–2019’ Proceedings, 15–17 May 2019, Vol. 2 (pp. 29–35). Jelgava, Latvia: Latvia University of Life Sciences and Technologies. DOI: 10.22616/rrd.25.2019.045.
- Giannitsopoulos, M.L., Burgess, P.J., & Rickson, R.J. (2019). Effects of conservation tillage systems on soil physical changes and crop yields in a wheat-oilseed rape rotation. *Journal of Soil and Water Conservation 2019*, 74(3), 247–258. DOI: 10.2489/jswc.74.3.247.
- Gozubuyuk, Z., Sahin, U., Adiguzel, M.C., Ozturk, I., & Celik, A. (2015). The influence of different tillage practices on water content of soil and crop yield in vetch–winter wheat rotation compared to fallow–winter wheat rotation in a high altitude and cool climate. *Agricultural Water Management*, 160, 84–97. DOI: 10.1016/J.AGWAT.2015.07.003.
- Hiel, M.P., Barbieux, S., Pierreux, J., Olivier, C., Lobet, G., Roisin, C., Roisin, C., Garré, S., Colinet, G., Bodson, B., & Dumont, B. (2018). Impact of crop residue management on crop production and soil chemistry after seven years of crop rotation in temperate climate, loamy soils. *PeerJ*, 6, e4836. DOI: 10.7717/peerj.4836.
- Jug, I., Jug, D., Sabo, M., Stipešević, B., & Stošić, M. (2011). Winter wheat yield and yield components as affected by soil tillage systems. *Turkish Journal of Agriculture and Forestry*, 35(1), 1–7. DOI: 10.3906/tar-0909-376.
- Kirkegaard, J., Christen, O., Krupinsky, J., & Layzell, D. (2008). Break crop benefits in temperate wheat production. *Field Crops Research*, 107 (3), 185–195. DOI: 10.1016/j.fcr.2008.02.010.
- Mazzilli, S.R., Ernst, O.R., de Mello, V.P., & Pérez, C.A. (2016). Yield losses on wheat crops associated to the previous winter crop: Impact of agronomic practices based on on-farm analysis. *European Journal of Agronomy*, 75, 99–104. DOI: 10.1016/j.eja.2016.01.007.
- Ozpinar, S. (2006). Effects of tillage on productivity of a winter wheat-vetch rotation under dryland Mediterranean conditions. *Soil and Tillage Research*, 89(2), 258–265. DOI: 10.1016/j.still.2005.07.009.
- Pittelkow, C.M., Linquist, B.A., Lundy, M.E., Liang, X., van Groenigen, K.J., Lee, J., van Gestel, N., Six, J., Venterea, R.T., & van Kessel, C. (2015). When does no-till yield more? A global meta-analysis. *Field Crops Research*, 183, 156–168. DOI: 10.1016/j.fcr.2015.07.020.

- Rieger, S., Richner, W., Streit, B., Frossard, E., & Liedgens, M. (2008). Growth, yield, and yield components of winter wheat and the effects of tillage intensity, preceding crops, and N fertilisation. *European Journal of Agronomy*, 28(3), 405–411. DOI: 10.1016/j.eja.2007.11.006.
- Schillinger, W.F., & Paulitz, T.C. (2018). Canola versus wheat rotation effects on subsequent wheat yield. *Field Crops Research*, 223, 26–32. DOI: 10.1016/J.FCR.2018.04.002.
- Schlegel, A.J., Assefa, Y., Haag, L.A., Thompson, C.R., & Stone, L. (2017). Long-term Tillage on Yield and Water Use of Grain Sorghum and Winter Wheat. *Agronomy Journal*, 110(1), 269–280. DOI: 10.2134/agronj2017.02.0104.
- Smagacz, J., Koziel, M., & Martyniuk, S. (2016). Soil properties and yields of winter wheat after long-term growing of this crop in two contrasting rotations. *Plant Soil Environ.*, 62, 566–570. DOI: 10.17221/582/2016-PSE.
- Vyn, J., Sutton, J.C., & Raimbault, B.A. (1991). Crop sequence and tillage effects on winter wheat development and yield. *Canadian Journal of Plant Science*, 676(71), 669–676. DOI: 10.4141/cjps91-099.

RESULTS OF *RIBES* BREEDING AT THE NATIONAL UNIVERSITY OF LIFE AND ENVIRONMENTAL SCIENCES OF UKRAINE

*Volodymyr Mezhenskyj, Tetiana Kondratenko, Borys Mazur, Nataliia Shevchuk, Yurii Andrusyk, Oksana Kuzminets

National University of Life and Environmental Sciences of Ukraine, Ukraine

*Corresponding author's email: mezh1956@ukr.net

Abstract

Breeding work on *Ribes* species has been started at the National University of Life and Environmental Sciences of Ukraine in Kyiv since 1984 by Petro Sherenhovyy. The breeding programme has been focused on fruit quality, yield, resistance to diseases and pests, as well as on adaptive responses to environmental conditions. As a result of the long-term work, 18 new cultivars were included in the State Register of Plant Varieties of Ukraine in 1999–2016. The aim of this paper is to describe these varieties: 10 blackcurrant ('Dochka Vorskly', 'Hovtva', 'Pam'yati Leonida Mykhalevskoho', 'Universytetska', 'Aspirantska', 'Didorivska', 'Poltava 584', 'Petrivska', 'Yuvileina Sherenhovoho', and 'Leleka'), 5 redcurrant ('Kyianochka', 'Poliana Holosiivska', 'Buzhanska', 'Malva', and 'Olha'), 1 whitecurrant ('Lebidka'), and 2 gooseberry ('Vasylo', and 'Tikych'). The varieties described give farmers and scientists the best knowledge about these cultivars with good level of commercial traits, suitable for dissemination in Ukraine.

Key words: blackcurrant, whitecurrant, redcurrant, goldencurrant, gooseberry, cultivars.

Introduction

The genus *Ribes* L. (*Grossulariaceae*) includes some edible gooseberries and currants which are among popular small fruit crops in Ukraine. Fruit currants are divided into blackcurrant (*R. nigrum* L.), red and whitecurrant (*Ribes petreum* Wulfen, *R. rubrum* L., *R. spicatum* E. Robson and their interspecies hybrids) and goldencurrant (*R. aureum* Pursh.). Most gooseberry cultivars belong to hybrids between European *R. uva-crispa* L. and some American species. Both gooseberry and currant cultivars are widely grown in commercial and amateur orchards in Ukraine. *Ribi* occupy quite significant areas of small fruit crops in Ukraine. The area of currant plantations at bearing age makes 4.8 thousand ha and the area of the gooseberry plantations makes 0.5 thousand ha, which are 24.1% and 2.5% of total berries area, respectively. Ukrainian currant production estimated annually is estimated roughly at 27.1 thousand t, and gooseberry production is estimated at 7.8 thousand t (State..., 2018). The State Register of Plant Varieties Suitable for Dissemination in Ukraine in 2020 (Ministry..., 2020) includes 26 blackcurrant cultivars, 11 red and white currant cultivars, and 21 gooseberry cultivars. The main breeding institutions in this field in Ukraine are Institute of Horticulture, including Lviv Experimental Station and Mliiv Experimental Station of Pomology, and National University of Life and Environmental Sciences of Ukraine (bellow written as NULESU) (Bronovytska, 2013).

The breeding work on *Ribes* was started at the NULESU (former Ukrainian Agricultural Academy) in 1984 (Sherenhovyi, 2011). Petro Sherengovyi, as the founder of the breeding program, used methods of cross breeding, either via controlled crosses or via open pollination as well as bud sports. Initial material

was the varieties of small fruit crop early collected by Sherenhovyi which included a lot of berries, including 98 blackcurrant cultivars. Selections were made in large number of seedlings based initially on subjective evaluation of fruit quality, yield, and plant health. The breeding tasks in blackcurrant breeding are stable high yield (10–15 t ha⁻¹), large fruit (1.5–2.5 g), high vitamin C content (150–200 mg 100 g⁻¹), adaptability to mechanized harvesting, and resistance to pests and diseases (Sedov, 1995). The yield size and fruit quality strongly depended on the environment (Zhuchenko, 1988). The final selections were used for the observation and replicated plots, and other studying (Sherenhovyy, 1999; Kondratenko & Sherenhovyi, 2007; Havuk, 2008; Silenko & Havuk, 2013). Most promising selections were tested according to guidelines for distinctness, uniformity, and stability tests and registered in Ukraine as new cultivars. The employees of the Department of Horticulture participated in the development of a number of Sherenhovyi's breeding varieties. Brief information about some varieties given by the principal breeder (Sherenhovyy, 1999, 2011) needs to be supplemented. The aim of this paper is to review all cultivars of *Ribes* species developed at the NULESU.

Materials and Methods

The blackcurrant, white currant, redcurrant, and gooseberry cultivars developed at the NULESU were recollected in the new collection. The collection site was established in the training laboratory 'Fruit and Vegetable Garden' of the NULESU in 2015–2016. The studies were carried out according to generally accepted methods (Sedov, 1995; Sedov & Ogoltsova, 1999). A monograph method was used during studying process for describing. The description of

18 registered varieties is reported below, including 10 blackcurrant, 5 redcurrant, 1 whitecurrant, and 2 gooseberry cultivars.

Results and Discussion

Registered blackcurrant cultivars

'Dochka Vorskly' was obtained from open pollination of 'Vorskla' in 1978. The plants are resistant to powdery mildew (causal agent *Podosphaera mors-uvae* (Schwein.) U. Braun & S. Takam.) and white pine blister rust (causal agent *Cronartium ribicola* J. C. Fisch.), and medium resistant to septoriosiis (causal agent *Mycosphaerella ribis* (Fuckel) Lindau). Cultivar is suitable for a combine harvester. Cropping is stable and abundant (16 t ha⁻¹). The plants are medium-sized with thick first grow shoots. The strigs are medium, medium-dense. The berries are wide-oval, black, shiny, attractive. The average fruit weight is 1.5 g, the largest fruit is up to 3.5 g. The skin is thick, but not rough, dense. The flesh is greenish-brown, a pleasant sour-sweet, slightly currant aroma. The berries have soluble solids (18.5–20.8%), sugars (8.6%), organic acids (1.8%), vitamin C (up to 200 mg 100 g⁻¹). Ripening season is medium-early. Fruit is used for fresh consumption and freezing as well as for various types of technical processing. The variety was included to the State Register of Plant Varieties of Ukraine in 1999.

'Hovtva' was obtained from open pollination of 'Poltava 800' × 'Belorusskaya Sladkaya' in 1978. The plants are resistant to powdery mildew and white pine blister rust. Cropping is stable and abundant (15 t ha⁻¹). The plants are medium-sized, semi-spreading. The first grow branches are thick, upright. The strigs are middle to long. The average fruit weight is 1.3 g, the largest fruit is up to 2.6 g. The skin is not thick, tight. The flesh is greenish-brown, pleasantly sour-sweet in taste. The berries have soluble solids (13.1%), sugars (7.6%), organic acids (3.2%), vitamin C (190 mg 100 g⁻¹). Ripening season is medium. Fruit is used for processing. The variety has been included in the State Register of Plant Varieties of Ukraine since 1999.

'Pam'yati Leonida Mykhalevskoho' is a sport of 'Mriia Kyivska' (= 'Nestor Kozin' × 'Seenets Golubki'). The plants are resistant to powdery mildew and septoriosiis, only in some years affected by white pine blister rust. Cropping is stable and abundant (18–20 t ha⁻¹). The plants are medium-sized, semi-spreading, with dark green leaves. The strigs are medium, dense, at 2–3 in node. The berries are round-oval, black, shiny. The average fruit weight is 1.2 g, the largest fruit is up to 3.0 g. The skin is tight, elastic. The flesh is greenish-yellow, sour-sweet, slightly of currant aroma. The berries have soluble solids (13.2–14.7%), sugars (7.9–8.2%), organic acids (2.0–2.4%), vitamin C (195–220 mg 100 g⁻¹). Ripening season is

mid-late. Fruit is used for fresh consumption, freezing, and processing. The variety was included in the State Register of Plant Varieties of Ukraine in 2007.

'Universytetska' was obtained from open pollination of 'Holosiivska' (= 'Poltava 800' × 'Zelena Dymka') in 1992. The plants are resistant to powdery mildew and white pine blister rust. Cultivar is suitable for a combine harvester. Cropping is stable and abundant (19 t ha⁻¹). The plants are medium-sized, compact. The first grow branches are thick, yellow-brown, with pink-purple densely arranged buds. The strigs are long, medium-dense, abundant, up to 12 berries. The berries are round-oval, black, shiny. The average fruit weight is 1.2 g, the largest fruit - up to 3.0 g. The skin is thin, but tight. The flesh is yellowish-greenish, pleasantly sour-sweet in taste, with a slight currant aroma. The berries have soluble solids (16.1%), sugars (8.4%), organic acids (3.5%), vitamin C (215–230 mg 100 g⁻¹). Ripening season is mid-late. Fruit is used for fresh consumption as well as for various types of technical processing. The variety has been included in the State Register of Plant Varieties of Ukraine since 2007.

'Aspirantska' was obtained by crossing 'Mriia Kyivska' (= 'Nestor Kozin' × 'Seenets Golubki') × 'Narodna' (= F₁ 'Lentyaj') in 1995. The plants are self-fertile, resistant to fungal diseases, only in some years they were affected by powdery mildew. Drought resistance is high. Cropping is abundant (15 t ha⁻¹). The plants are medium-sized, compact; branches are thick. The leaves are small, light green. The strigs are medium to long averaging 6–8 large berries. The berries are round, black, shiny. The average fruit weight is 1.8 g, the largest fruit - up to 3.8 g. The skin is of medium density, elastic. Flesh is greenish-yellow, with a very pleasant sour-sweet taste. The berries have soluble solids (13.7–14.2%), sugars (9.2–10.3%), organic acids (2.4–2.5%), vitamin C (241–263 mg 100 g⁻¹). Ripening season is medium. The fruit does not fall off for a long time. They are suitable for fresh consumption as well as for freezing and processing. The variety has been included in the State Register of Plant Varieties of Ukraine since 2008.

'Didorivska' was obtained by crossing 'Dochka Vorskly' (= F₁ 'Vorskla') × 'Mriia Kyiva' (= 'Nestor Kozin' × 'Seenets Golubki') in 1995. The plants are self-fertile, resistant to powdery mildew, only in some years they were affected by white pine blister rust. Drought resistance is high. Cropping is abundant (17 t ha⁻¹). The plants are medium-sized to large, compact; branches are thick, elastic. The leaves are five-lobed, dark salad coloration, lighter on the tips of shoots; lower lobe is slightly expressed; margin is sharply toothed; petioles are long. The strigs are medium to long averaging 6–8 large berries. The berries are round-oval, black, shiny, attractive. The average

fruit weight is 1.9 g, the largest fruit is up to 4.3 g. The skin is dense, elastic. Flesh is greenish-yellow, pleasantly sour-sweet in taste. The berries have soluble solids (13.7–14.2%), sugars (9.2–10.2%), organic acids (2.4–2.6%), vitamin C (238–251 mg 100 g⁻¹). Ripening season is middle. The fruit does not fall off for a long time. They are suitable for fresh consumption, freezing, and processing. The variety has been included in the State Register of Plant Varieties of Ukraine in 2009.

‘Poltava 584’ (‘Poltava Pokrashchena’) was obtained by crossing ‘Poltava 800’ (= ‘Zoya’ × ‘Prymorskij Chempion’) × ‘Titania’ in 1995. The plants are field resistant to powdery mildew. Cropping is abundant, up to 6 kg per bush. The plants are vigorous, compact, with many shoots. The strigs are medium. The berries are round, black, shiny. The average fruit weight is 1.8 g, the largest fruit – up to 4.5 g. The skin is dense, elastic. The flesh is yellowish and light greenish, sweet and sour in taste. The berries have soluble solids (13.9%), sugars (10.8%), pectins (1.9%), organic acids (3.1–3.2%), vitamin C (215–320 mg 100 g⁻¹). They are used for fresh consumption, as well as for jam, juices, jellies, wine, and freezing. The variety has been included in the State Register of Plant Varieties of Ukraine since 2014.

‘Petrivska’ was obtained by crossing ‘Mriia Kyivska’ (= ‘Nestor Kozin’ × ‘Seenets Golubki’) × ‘Holosiivskyi Veleten’ [= ‘Pam`yatna’ × (‘Perun’ × ‘Titania’)] in 1990. The plants are resistant to powdery mildew and anthracnose (causal agent *Drepanopeziza ribis* (Klebahn) von Höhnel), medium resistant to white pine blister rust and blackcurrant gall mite (*Cecidophyopsis ribis* (Westwood 1869)). Cropping is abundant – 3.9 kg per bush (18.6 t ha⁻¹). The plants are medium-sized, often large, spreading. The shoots are thick, gray. The strigs are medium. The berries are black, relatively transportable. The average fruit weight is 1.6 g, the largest fruit is up to 4.5 g. The flesh is greenish, sour-sweet. The berries have soluble solids (14.5%), sugars (8.1–8.3%), organic acids (3.3–3.5%), vitamin C (190–250 mg 100g⁻¹). The harvest is mid-season. The variety has been included in the State Register of Plant Varieties of Ukraine since 2015.

‘Yuvileina Sherenhovoho’ is a sport of ‘Holosiivskyi Veleten’ [= ‘Pam`yatna’ × (‘Perun’ × ‘Titania’)]. The plants are resistant to fungal diseases. Cropping is abundant - 4–7 kg per bush (18–24 t ha⁻¹). The plants are medium-sized, often large, spreading. The shoots are thick, gray. The strigs are short. The berries are black, early ripening. The average fruit weight is 1.8 g, the largest fruit is up to 2.4 g. The flesh is greenish-yellow, sour-sweet in taste. The berries have soluble solids (14.5%), sugars (8.2%), pectins (1.7%), organic acids (3.4%), vitamin C (220 mg 100 g⁻¹). The variety has been included in

the State Register of Plant Varieties of Ukraine since 2016.

‘Leleka’ was obtained by crossing ‘Mriia Kyiva’ (= ‘Nestor Kozin’ × ‘Seenets Golubki’) × ‘Narodna’ (= F₁ ‘Lentyaj’) in 1995. The plants are self-fertile, resistant to powdery mildew, anthracnose, and white pine blister rust. Cultivar is suitable for a combine harvester. The plants are vigorous, compact. The shoots are elastic, thick. The strigs are long averaging 8–12 large berries. The berries are round-oval, black, shiny. The average fruit weight is 1.7 g, the largest fruit is up to 3.5 g. The skin is thin, but tight. The flesh is tight, elastic. The flesh is greenish-yellow, sweet and sour, aromatic. The berries have soluble solids (14.2–14.6%), sugars (8.4–9.2%), organic acids (2.2–3.0%), vitamin C (225–236 mg 100 g⁻¹). Ripening season is medium. Fruit is used for fresh consumption, freezing, and various types of technical processing (juices, jellies, compotes, and wine materials). The variety has been included in the State Register of Plant Varieties of Ukraine since 2017.

Registered redcurrant cultivars

‘Kyianochka’ was obtained by crossing ‘Jonkheer van Tets’ × ‘Fay’s Prolific’ in 1986. The plants are resistant to most fungal diseases, but they are susceptible to septoriosiis. Cropping is stable and abundant (21 t ha⁻¹). The plants are vigorous in youth, and medium-sized with age, slightly spreading. The shoots are thick. The leaves are medium-sized, dark green, slightly curved inside. The strigs are medium to long, having up to 17 berries. The berries are dark red, round, attractive for early season. The average fruit weight is 0.9 g, the largest fruit is up to 1.0 g. The flesh is light pink, sweet and sour, aromatic. The berries have soluble solids (11.0%), sugars (6.9%), pectins (0.4%), organic acids (2.7%), vitamin C (47.0 mg 100 g⁻¹). They are used for processing, especially for jelly and juice. The variety has been included in the State Register of Plant Varieties of Ukraine since 2012.

‘Poliana Holosiivska’ was obtained by crossing ‘Buzhanska’ × (‘Jonkheer van Tets’ + ‘Kyianochka’) in 1999. The plants are resistant to powdery mildew and anthracnose, and semi-resistant to septoriosiis. Cropping is very abundant (up to 24 t ha⁻¹). The plants are medium-sized with age, slightly spreading. The strigs are very long. The berries are bright red, shiny. Average fruit weight is 0.8 g. The berries have soluble solids (11.1%), sugars (7.0%), pectins (0.4%), organic acids (2.6%), vitamin C (46.0 mg 100 g⁻¹). Ripening season is medium. The fruit is used for processing. The variety has been included in the State Register of Plant Varieties of Ukraine since 2012.

‘Buzhanska’ was obtained by crossing ‘Fay’s Prolific’ × ‘Red Cross’ in 1994. The plants are tolerant to powdery mildew, anthracnose, and septoriosiis. Cropping is abundant (22 t ha⁻¹). The plants are

medium-sized, slightly spreading. The shoots are thick, strong, and elastic. The strigs are medium to long, averaging 10–14 berries. The berries are bright red, attractive. The average fruit weight is 0.9 g, the largest fruit up to 1.5 g. The skin is thin but tight. The flesh is light red, with sweet and sour taste. The berries have soluble solids (11.9%), sugars (8.9%), organic acids (2.4%), vitamin C (58.4 mg 100 g⁻¹). Ripening season is early-middle/ mid-early?. Fruit is used for fresh consumption as well as for processing, including wine, juice, jelly, and freezing. The variety has been included in the State Register of Plant Varieties of Ukraine since 2014.

‘Malva’ was obtained by crossing ‘Poliana Holosiivska’ × (‘Buzhanka’ + ‘Kyianochka’) in 1999. The plants are resistant to anthracnose and septoriosis. Cropping is abundant (22 t ha⁻¹). The plants are compact. The shoots are thick, strong, and elastic. The strigs are long, up to 22 berries. The berries are slightly oval, dark red, shiny. The average fruit weight is 0.8 g, the largest fruit – up to 1.2 g. The skin is thin, but tight. The flesh is light red, with sweet and sour taste. The berries have soluble solids (11.2%), sugars (8.0%), pectins (0.4%), organic acids (2.5%), vitamin C (49.5 mg 100 g⁻¹). Fruit is used for fresh consumption, freezing, and processing. The variety has been included in the State Register of Plant Varieties of Ukraine since 2014.

‘Olha’ was obtained by crossing ‘Buzhanka’ × ‘Kyianochka’ in 2003. The plants are resistant to powdery mildew, anthracnose, and septoriosis. Cropping is abundant (4.5 kg per bush or 21.4 t ha⁻¹). The plants are robust, a little spreading, with thick shoots. The strigs are middle-sized averaging 10–12 large berries. The berries are dark red. The average fruit weight is 1.2 g, the largest fruit is up to 1.8 g. The skin is thin, but tight. The flesh is light pink, sweet and sour in taste. The berries have soluble solids (12.5%), sugars (8.0%), organic acids (2.9%), vitamin C (62.5 mg 100 g⁻¹). Fruit is used for fresh consumption and processing. The variety has been included in the State Register of Plant Varieties of Ukraine since 2016.

Registered whitecurrant cultivar

‘Lebidka’ obtained from open pollination seed of unknown variety. The plants are tolerant to fungal diseases. Cropping is abundant (up to 23 t ha⁻¹). The plants are medium-sized, slightly spreading. The shoots are thick, strong, and elastic, required pinching or trimming for branching. The leaves are trilobate, original shape, with lateral lobes, elongated parallel to the central vein. The strigs are medium-size. The berries are round, white, transparent, sour-sweet, rich-tasting. The average fruit weight is 0.9 g, the largest fruit – up to 1.3 g. The skin is thin. The berries have soluble solids (13.2%), sugars (6.6–8.0%), pectins (0.4%), organic acids (1.1–1.2%), vitamin C (65.0

mg 100 g⁻¹). Ripening season is early. Fruit is used for fresh consumption and all kind of processing, especially for wine making. The variety has been included in the State Register of Plant Varieties of Ukraine since 2014.

Registered gooseberry cultivars

‘Vasytko’ was obtained by crossing ‘Finik’ × ‘NAU 1’ (= F₁ ‘Afrykanets’). The plants are very productive, spineless, resistant to powdery mildew. They are medium-sized with inclined shoots. Young leaves are dark green, acute at the base. The flowers have moderate anthocyanin coloration. The berries are round-oval, light green, without pubescence. The average fruit weight is 2.9–3.3 g, the largest fruit is above 5.0 g. The skin is semi-thick, dense, elastic, with clearly visible subcutaneous veins. The flesh is greenish, sour-sweet. The berries have soluble solids (12.0%), sugars (5.3%), organic acids (2.4%), vitamin C (36.0–40.3 mg 100 g⁻¹). Fruit is used for fresh consumption, freezing, and processing. The variety has been included in the State Register of Plant Varieties of Ukraine since 2013.

‘Tikych’ was obtained by crossing ‘Neslukhovskiy’ × ‘Afrykanets’ in 1995. The plants are very productive, spineless, resistant to powdery mildew and septoriosis. Cropping is very abundant (10 kg her bush or 30 t ha⁻¹). The plants are medium-sized; the thick shoots are moderately covered with single and double spines. Flowering usually begins around April 20 and ends around May 1. The first harvest comes in late June. The berries are oval, violet-red. The average fruit weight is 3.8 g, the largest fruit – up to 7.0 g. The berries have soluble solids (14.1%), sugars (8.2%), organic acids (2.5%), vitamin C (55.5 mg 100 g⁻¹). Fruit is used for fresh consumption, freezing, as well as for various types of processing. The variety has been included in the State Register of Plant Varieties of Ukraine since 2013.

Goldencurrant cultivars

In the NULESU, while carrying out the breeding programme on *Ribes* species, some goldencurrant cultivars, such as ‘Monastyrskya’, ‘Perlyna Didorivky’, ‘Pyriatynska’, ‘Vyshneva’, ‘Yantarna’ and others were also developed. Goldencurrant is popular in amateur gardening, but there are not registered cultivars yet.

The new varieties developed at NULESU correspond to breeding tasks. They are resistant to main diseases, have high fruit quality, suitability for fresh market and processing, and good adaptability to condition of the northern part of Ukraine. Their drought tolerance may allow them to occupy a wider cultural range in a changing climate. Similarly, successful results in both red and white currants breeding as well as gooseberry breeding in terms of productivity and fruits quality in order to meet the set breeding tasks were obtained. Due to this, new

varieties are in demand by farmers. There is a great potential for further improvement of these small fruit crops. The cultivars developed at the NULESU and involved in breeding is good basis for new better varieties with high level of commercial traits.

Conclusions

The total number of *Ribes* cultivars developed in the NULESU and included in the State Register

of Plant Varieties of Ukraine in 1999–2016 was 18. These consisted of 10 blackcurrant, 5 redcurrant, 1 whitecurrant, and 2 gooseberry cultivars. They are resistant to main diseases, have high fruit quality, suitability for fresh market and processing, and good adaptability to local condition. The descriptions allow both farmers and scientists to know better the varieties suitable for dissemination in Ukraine.

References

- Bronovytska, M.A. (2013). Особливості формування сортових ресурсів смородини чорної (*Ribes nigrum* L.) в Україні (Peculiarities of blackcurrant (*Ribes nigrum* L.) varietal resources development in Ukraine). *Plant Varieties Studying and Protection*. 9(2), 15–19. (in Ukrainian).
- Havyuk, P.M. (2008). Urazhennia khvorobamy sortiv smorodyny chornoї (*Ribes nigrum* L.) selektsii NAU (Affection of blackcurrant (*Ribes nigrum* L.) varieties of National Agrarian University by diseases). *Plant Varieties Studying and Protection*. 4(1), 114–119. (in Ukrainian).
- Kondratenko, T.Ye., & Sherenhovi, P.Z. (2007). Seleksiia ta vyrobnytstvo plodiv smorodyny chornoї (Breeding and cultivation of black currant). *Sadivnytsvo*. 60, 159–168. (in Ukrainian).
- Ministry of Agricultural Policy and Food of Ukraine. *Derzhanvyi reestr sortiv roslyn Ukrainy prydatnykh dlia poshyrennia v Ukraini v 2020* (State Register of Plant Varieties Suitable for Dissemination in Ukraine in 2020). (2020). Retrieved March 26, 2020, from <https://sops.gov.ua/reestr-sortiv-roslyn>. (in Ukrainian).
- Sedov, E.N. (Ed.). (1995). *Programma i metodika selektsii plodovykh, yagodnykh i orekhoplodnykh kultur* (Programme and methods of breeding of fruit, small fruit, and nut crops). Orel: All-Russian Res. Inst. Breeding Fruit Crops. (in Russian).
- Sedov, E.N., & Ogoltsova, T.P. (Eds.). (1999). *Programma i metodika sortoizucheniya plodovykh, yagodnykh i orekhoplodnykh kultur* (Programme and methods of varietal study of fruit, small fruit, and nut crops). Orel: All-Russian Res. Inst. Breeding Fruit Crops. (in Russian).
- Sherenhovi, P.Z. (1999). Seleksiia yahidnykh kultur (Breeding of small fruit crops). *Sadivnytsvo*. 48, 58–62. (in Ukrainian).
- Sherenhovi, P.Z. (2011). *Moie zhyttia – v moikh sortakh* (My life is in my varieties). Vinnytsia: FOP D. Yu. Korzun. (in Ukrainian).
- Silenko, V.O., & Havyuk, P.M. (2013). Придатність сортів смородини (*Ribes nigrum* L.) селекції НУБіП України до механізованого збирання ягід (Suitability of black currant (*Ribes nigrum* L.) as bred by NULES of Ukraine to machine harvesting of its berries). *Plant Varieties Studying and Protection*. 9(3), 13–17. (in Ukrainian).
- State Statistics Service of Ukraine. (2018). *Silske hospodarstvo Ukrainy: Statystychnyi shchorichnyk 2017* (Agriculture of Ukraine: Statistical Yearbook 2017). Retrieved February 20, 2018, from http://www.ukrstat.gov.ua/druk/publicat/kat_u/2018/zb/09/zb_sg2017_pdf.pdf. (in Ukrainian).
- Zhuchenko, A.A. (1988). *Adaptivnyj potentsial kulturnykh rastenij: ekologo-geneticheskiye osnovy* (Adaptive potential of cultivated plants: ecologo-genetic basics). Kishinev: Shtiintsa (in Russian).

OCCURRENCE OF GENETIC LINEAGES OF *Puccinia striiformis* IN LATVIA

*Līga Feodorova-Fedotova^{1,2}, Biruta Bankina¹

¹Institute of Soil and Plant Sciences, Latvia University of Life Sciences and Technology, Latvia

²Institute of Plant Protection Research, Latvia University of Life Sciences and Technology, Latvia

*Corresponding author's email: liga.feodorova-fedotova@llu.lv

Abstract

Puccinia striiformis is a biotrophic pathogen able to cause broad scale epidemics in wheat growing regions. *P. striiformis* is genetically highly variable pathogen. New, aggressive genetic lineages, adapted to warm temperatures have been observed in the last decades worldwide. The study aimed to ascertain the structure of genetic lineages of *P. striiformis* in Latvia. Forty one wheat leaf samples with yellow rust symptoms were collected in 2017–2019. Fenotyping and genotyping methods were used for identification of genetic lineages in Global Rust Reference Center, Denmark. Assessments of leaf diseases on winter wheat differentials – ‘Ambition’, ‘Mariboss’, ‘Moro’, ‘Compair’, ‘Rendezvous’, ‘Spalding Prolific’ and local variety ‘Fredis’ were made during the research. Five genetic lineages of *P. striiformis* – PstS4, PstS7, PstS10, PstS13 and PstS14 were found. 56% from the samples belonged to PstS14, 17.1% PstS10, 12.2% PstS4 and PstS7, 2.4% PstS13. Genetic lineages identified from Latvian wheat samples are found in the biggest cereal growing regions in Europe and are able to cause epidemics on wheat. Genetic lineages of *P. striiformis* from Latvian samples have not been identified before. All differential varieties were infected with *P. striiformis* in 2017, ‘Ambition’ and ‘Moro’ in 2018, no infection was observed on differentials in 2019 despite the presence of *P. striiformis* on winter wheat variety ‘Fredis’. The identification of genetic lineages of *P. striiformis* on wheat in Latvia is necessary to continue.

Key words: yellow rust, identification, race typing.

Introduction

Yellow rust caused by *P. striiformis* is one of the main wheat diseases all over the world (Chen, 2005). In susceptible varieties, at early infection yellow rust can provoke 100% yield losses (Hovmöller *et al.*, 2016; Waqar *et al.*, 2018). Previously, it has been reported that *P. striiformis* is a temperate zone pathogen (Stubbs, 1985) requiring high relative humidity and air temperature from 8 °C to 12 °C for successful infection (Dennis, 1987; de Vallavieille-Pope *et al.*, 1995). Since 2000 epidemics of *P. striiformis* have been observed in high-temperature areas (Bayles *et al.*, 2000; Hovmöller *et al.*, 2011; Ali *et al.*, 2014), which could be explained by changes in pathogen's population. New *P. striiformis* races – Kranich, Warrior, Warrior(-), via mutations, somatic and sexual recombinations have appeared (Waqar *et al.*, 2018) and replaced races occurring before 2011 (Ali *et al.*, 2017). New genetic lineages and races are more aggressive, tolerant to warm air temperatures, have shorter latent period, and produce larger number of spores (Milus *et al.*, 2009), thus creating high possibility for epidemics.

An effective method for yellow rust control is the cultivation of wheat varieties containing resistance (Yr) genes. Different types of resistance like seedling resistance and adult plant resistance have been determined. Seedling resistance is provided by single genes and act in all plant growth stages unlike adult plant resistance when resistance performs at post-seedling stages (Chen *et al.*, 2014). The duration of host resistance can be influenced by pathogen virulence. Differential sets containing selected wheat

varieties with different resistance genes is a widely used tool for pathogen virulence detection (Sørensen, Thach, & Hovmöller, 2016). Differential sets include ‘world differentials’, ‘European differentials’ and some additional cultivars of lines with diverse resistance genes (Chen, 2005) allowing to identify a wide spectrum of genetic lineages and races. Race is defined as a pattern of pathogen and host reactions to inoculation onto host differential sets following gene to gene relationship principle (Hovmöller *et al.*, 2011). Virulence phenotyping is carried out in controlled conditions because of pathogen sensibility of light, air temperature and moisture (Vallavieille-Pope *et al.*, 1995; Vallavieille-Pope *et al.*, 2002). For successful inoculation, alive spore samples are necessary (Hovmöller *et al.*, 2011).

Different molecular methods – amplified fragment length polymorphism (AFLP), random amplified polymorphic DNA (RAPD), restriction fragment length polymorphism (RFLP), single nucleotide polymorphism (SNP) markers and simple sequence repeats (SSR) have been used to understand genetic structures of the pathogen (McDonald, 1997). Polymerase chain reaction (PCR) is successfully used for biotrophic fungi detection from infected host tissue (Fraije *et al.*, 2001; Wang *et al.*, 2017). As *P. striiformis* has genetic stability and genome specificity, genome-specific primers have been developed (Wang *et al.*, 2008). PCR provides rapid and reliable detection of *P. striiformis* before the visual symptoms of the disease have appeared on host leaves. A various number of studies have been performed in relation to the identification of *P. striiformis* genetic lineages with

molecular methods worldwide (Ali *et al.*, 2010; Wan & Chen, 2014; Walter *et al.*, 2016).

Yellow rust has been observed in Latvia periodically (Bankina, Jakobija, & Bimsteine, 2011) and some studies about the possibilities of biological control of yellow rust in field conditions have been started (Feodorova-Fedotova, Bankina, & Strazdina, 2019). Detailed researches in molecular level and race identification are required.

The objective of this research was to identify the genetic lineages of *P. striiformis* from the wheat leaf samples collected in Latvia 2017–2019.

Materials and Methods

During the research, wheat leaves with clearly visible yellow rust symptoms were collected in Latvia 2017–2019. In addition, samples were taken from winter wheat differentials. Wheat leaf sample collection procedure was worked out by Global Rust Reference Center (GRRC). From each field 3–5 leaves with visible pustules of *P. striiformis* urediniospores were taken. Green, young leaves without signs of any other plant pathogens were preferred. Each leaf was folded (pustules stayed inside) and put into a paper bag. Leaves were pressed and dried for 24 hours in room temperature. After drying paper bags were put into the paper envelope, sealed with a tape and labelled with a unique ID, and sent to GRRC for race identification. Additional information about the collection date, wheat variety, plant growth stage, which leaf was collected, plant protection products used and field coordinates of each sample were recorded.

Virulence phenotyping performed in GRRC, Denmark was used for genetic lineage identification in all years of research (Hovmøller *et al.*, 2017). Twenty wheat genotypes from world and European differential sets were sown in substrate suitable for cereals. Phenotyping was carried out in controlled conditions with 16 hours day period and temperature 17 °C during and 12 °C during the night period (Sørensen *et al.*, 2016). Seedlings were inoculated at the two-leaf stage and placed in dew chamber at 10 °C for

24 h (Wan & Chen, 2010). Differential responses were evaluated two to three weeks after inoculation (Bayles *et al.*, 2000). For the assessments 0–9 scale was used (Chen *et al.* 2014). Infection type scores 7–9 indicate wheat susceptibility and pathogen virulence, while infection type scores 0–6 indicate wheat resistance and pathogen avirulence.

For molecular genetic lineage characterization, simple sequence repeats (SSR) were used (Bailey *et al.*, 2015).

Six winter wheat differentials – ‘Ambition’, ‘Mariboss’, ‘Moro’, ‘Compair’, ‘Rendezvous’ and ‘Spalding Prolific’ were sown in the North-Western part of Latvia in 2017–2019. ‘Compair’ did not overwinter; therefore, the data from this cultivar were not obtained. Differentials were sown in six adjacent rows next to the local susceptible winter wheat variety ‘Fredis’. Assessments of wheat leaf diseases were made every week (from BBCH 32 to BBCH 75). If *P. striiformis* were present, samples of wheat leaves were taken and sent to GRRC for race identification.

Resistance to various *P. striiformis* genetic lineages is determined by resistance genes of differentials (Table 1). This information is used for the phenotyping.

Results and Discussion

Five genetic lineages of *P. striiformis* – PstS4, PstS7 (Warrior-), PstS10 (Warrior), PstS13 (Triticale2015) and PstS14 were identified during the research (Table 2).

The most common (56%) genetic lineage in Latvia was PstS14 (Figure 1; Figure 2). This genetic lineage is adapted to high temperatures and has caused epidemics in Morocco (Hovmøller *et al.*, 2018). Data show that the occurrence of PstS14 in Latvia has increased within the years (Table 2). PstS10 (17%) and PstS7 (12%) was distributed in 2017 and 2018 respectively, whereas PstS4 (12%) was common in 2017. PstS13 (3%) was found only in the first year of research and its occurrence was insignificant.

The composition of *P. striiformis* genetic lineages was diverse within the years of research. In 2017, five

Table 1

Resistance genes of differentials and the susceptibility to genetic lineages of *P. striiformis*

Differentials	Resistance genes	Genetic lineages of <i>P. striiformis</i> able to infect differentials
Ambition	Amb	PstS5, PstS7, PstS8, PstS9
Mariboss	Yr15	Resistant
Moro	Yr10	PstS2, PstS3, PstS4
Rendezvous	Yr17	PstS0, PstS1, PstS5, PstS6, PstS7, PstS8, PstS9, PstS10, PstS11, PstS12, PstS14
Compair	Yr8	PstS1, PstS2, PstS3, PstS4, PstS8, PstS11, PstS12, PstS13, PstS14
Spaldings Prolific	YrSp, Yr25	PstS1, PstS2, PstS3, PstS5, PstS7, PstS8, PstS9, PstS10, PstS12, PstS14

Table 2

Identified genetic lineages of *Puccinia striiformis* in Latvia 2017–2019, % from collected samples

	2017	2018	2019
PstS4	33	0	0
PstS7	13	29	5
PstS10	40	0	5
PstS13	7	0	0
PstS14	7	71	90

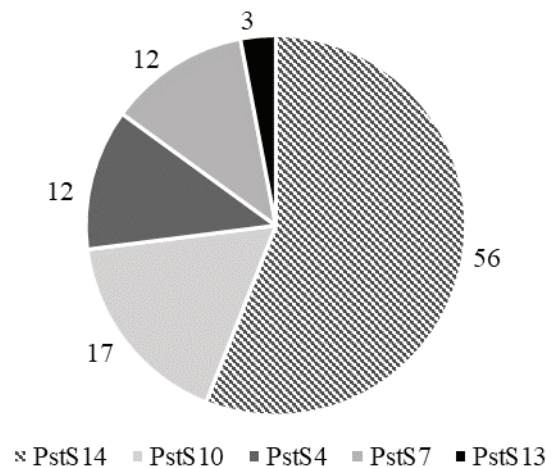


Figure 1. Composition of genetic lineages of *P. striiformis* identified in Latvia, 2017–2019, %.

different genetic lineages were identified – PstS4, PstS7, PstS10, PstS13 and PstS14. In 2018 PstS7, PstS14 and in 2019 PstS7, PstS10, PstS14 were found (Table 2).

All of the identified genetic lineages are considered aggressive (Hovmöller *et al.*, 2018) and may initiate new epidemics (Brown & Hovmöller, 2002). More attention to *P. striiformis* has been paid after 2009 due to the emergence of new races causing economically significant epidemics. PstS4 were common on triticale in Scandinavia 2009–2011, whereas PstS7 and PstS10 were ones of the main genetic lineages on wheat in Europe since 2011 (Ali *et al.*, 2017) and have replaced genetic lineages occurred before. PstS13 dominates in South America (Argentina, Chile) and have caused epidemics on wheat and triticale in 2018. PstS14 the first time was detected in 2016 from samples collected in Morocco (Hovmöller *et al.*, 2018).

In Latvia, genetic lineage identification of *P. striiformis* has not been performed before. The obtained data confirm the presence of aggressive genetic lineages of *P. striiformis* in Latvia. Information of virulence phenotype of identified genetic lineages allows choosing resistant wheat varieties for cultivation.

Various infection of *P. striiformis* was observed in field trials on differentials during the research. Winter

wheat variety ‘Fredis’ was infected in all years, PstS7, PstS10 and PstS14 were identified from the samples.

In conformity with resistance genes, assessed differentials are susceptible to PstS0, PstS1, PstS2, PstS3, PstS4, PstS5, PstS6, PstS7, PstS8, PstS9, PstS10, PstS11, PstS12, PstS13 and PstS14 genetic lineages. All differentials were infected with *P. striiformis* in 2017. A year later only ‘Ambition’ and ‘Moro’ were infected but in 2019 no symptoms of yellow rust were observed on differentials (Table 3). According to the resistance genes and identified genetic lineages of *P. striiformis*, ‘Ambition’ should be infected in 2019. The low infection level and irregular distribution of yellow rust could explain the absence of *P. striiformis* on differentials in 2019. Although winter wheat ‘Mariboss’ should be resistant to PstS4, PstS7, PstS10, PstS13 and PstS14, infection on this variety was observed in 2017. A new, unidentified genetic lineages could be present in Latvia. Winter wheat variety ‘Moro’ was infected with yellow rust in 2018 (Table 3), when PstS14 genetic lineage was identified.

The obtained data, although contradictory, provide first insight in genetic diversity and virulence of *P. striiformis* in Latvia. The research on genetic lineage typing of *P. striiformis* needs to be continued.



Figure 2. Identified genetic lineages and spatial distribution of *P. striiformis* in Latvia 2017–2019.

Table 3

Infection of winter wheat differentials with yellow rust in field trials, 2017–2019

Winter wheat differential	2017		2018		2019	
	Should be infected in accordance of detected races	Infection	Should be infected in accordance of detected races	Infection	Should be infected in accordance of detected races	Infection
Ambition	×	×	×	×	×	–
Mariboss	–	×	–	–	–	–
Moro	×	×	–	×	–	–
Rendezvous	×	×	×	–	×	–
Spalding Prolific	×	×	×	–	×	–

Conclusions

Genetic lineages that have caused epidemics in the biggest wheat growing regions are identified in Latvia.

Identified genetic lineages—PstS4, PstS7 (Warrior-), PstS10 (Warrior), PstS13 (Triticale2015) and PstS14 cover a wide spectrum of virulence phenotype.

Acknowledgements

The research was financed by the Latvia Ministry of Agriculture project ‘Distribution of yellow rust

disease causal agent *Puccinia striiformis*, Wes. races in Latvia and measures to minimize the damage in wheat fields’ and Latvia University of Life sciences and Technologies project ‘Identification of the races of yellow rust causal agent *Puccinia striiformis* and evaluation of wheat varieties resistance against yellow rust in the laboratory conditions’.

Authors are grateful to Global Rust Reference Center for race identification.

References

Ali, M., Ji, W.Q., Hu, Y.G., Baloch, G.M., Zhong, H., & Wang, C.Y. (2010). Molecular implications from Ssr markers for stripe rust (*Puccinia striiformis* f. sp. *tritici*) resistance gene in bread wheat line N95175. *Pak. J. Bot.*, 42(1), 383–390.

- Ali, S., Gladieux, P., Leconte, M., Gautier, A., Justesen, A.F., Hovmøller, M.S., de Vallavieille-Pope, C. (2014). Origin, migration routes and worldwide population genetic structure of the wheat yellow rust pathogen *Puccinia striiformis* f.sp. *tritici*. *PLoS Pathog*, 10(1), e1003903. DOI: 10.1371/journal.ppat.1003903.
- Ali, S., Rodriguez-Algaba, J., Thach, T., Sørensen, C.K., Hansen, J.G., Lassen, P., ... Hovmøller, M.S. (2017). Yellow rust epidemics worldwide were caused by pathogen races from divergent genetic lineages. *Front. Plant Sci.*, 8, 1557. DOI: 10.3389/fpls.2017.01057.
- Bankina, B., Jakobjija, I., & Bimsteine, G. (2011). Peculiarities of wheat leaf disease distribution in Latvia. *Acta Biol. Univ. Daugavp.*, 11(1), 47–54. DOI: 10.5586/aa.2005.059.
- Bailey, J., Karaoglu, H., Wellings, C.R., & Park, R.F. (2015). PCR-based simple sequence repeat markers for diagnostic identification of major clonal lineages of *Puccinia striiformis* f. sp. *tritici* and related stripe rust pathogens in Australia. *Australasian Plant Pathol.*, 44, 97–103. DOI: 10.1007/s13313-014-0326-3.
- Bayles, R., Flath, K., Hovmøller, M., & de Vallavieille-Pope, C. (2000). Breakdown of the Yr17 resistance to yellow rust of wheat in northern Europe. *Agronomie*, 20, 805–811. DOI: 10.1051/agro:2000176.
- Brown, J.K.M., & Hovmøller, M.S. (2002). Aerial dispersal of fungi on the global and continental scales and its consequences for plant disease. *Science*, 297, 537–541.
- Chen, W., Wellings, C., Chen, X., Kang, Z., & Liu, T. (2014). Wheat stripe (yellow) rust caused by *Puccinia striiformis* f. sp. *tritici*. *Molecular Plant Pathology*, 15(5), 433–446. DOI: 10.1111/mpp.12116.
- Chen, X.M. (2005). Review / Synthèse Epidemiology and control of stripe rust [*Puccinia striiformis* f. sp. *tritici*] on wheat. *Canadian Journal of Botany*, 27, 314–337. DOI: 10.1071/ar07045.
- Dennis, J.I. (1987). Temperature and wet-period conditions for infection by *Puccinia striiformis* f. sp. *tritici* race 104e137a+. *Trans. Br. Mycol.*, 88(1), 119–121. DOI: 10.1007/BF02879166.
- Feodorova-Fedotova, L., Bankina, B., & Strazdina, V. (2019). Possibilities for the biological control of yellow rust (*Puccinia striiformis*) in winter wheat in Latvia in 2017–2018. *Agronomy Research*, 17(3), 716–724. DOI: 10.15159/AR.19.137.
- Fraije, B.A., Lovell, D.J., Coelho, J.M., Baldwin, S., & Hollomon, D.W. (2001). PCR-based assays to assess wheat varietal resistance to blotch (*Septoria tritici* and *Stagonospora nodorum*) and rust (*Puccinia striiformis* and *Puccinia recondita*) diseases. *European Journal of Plant Pathology*, 107, 905–917. DOI: 10.1023/a:1013119206261.
- Hovmøller, M.S., Sørensen, C.K., Walter, S., & Justesen, A.F. (2011). Diversity of *Puccinia striiformis* on cereals and grasses. *Annual Review of Phytopathology*, 49(1), 197–217. DOI: 10.1146/annurev-phyto-072910-095230.
- Hovmøller, M.S., Walter, S., Bayles, R.A., Hubbard, A., Flath, K., Sommerfeldt, N., de Vallavieille-Pope, C. (2016). Replacement of the European wheat yellow rust population by new races from the centre of diversity in the near-Himalayan region. *Plant Pathology*, 65(3), 402–411. DOI: 10.1111/ppa.12433.
- Hovmøller, M.S., Rodriguez-Algaba, J., Thach, T., & Sørensen, C.K. (2017). Race typing of *Puccinia striiformis* on wheat. *Wheat Rust Diseases*, 1659, 29–40. DOI: 10.1007/978-1-4939-7249-4.
- Hovmøller, M.S., Rodriguez-Algaba, J., Thach, T., Justesen, A.F., & Hansen, J.G. (2018). *Report for yellow rust race analysis 2018*. GRRC, Aarhus University, Denmark, 1–8. Retrieved February 16, 2020, from https://agro.au.dk/fileadmin/www.grcc.au.dk/International_Services/Pathotype_YR_results/Summary_of_Puccinia_striiformis_molecular_genotyping_2018.pdf.
- McDonald, B.A. (1997). The population genetics of fungi: tools and techniques. *Phytopathology*, 87, 448–453.
- Milus, E.A., Kristensen, K., & Hovmøller, M.S. (2009). Evidence for increased aggressiveness in a recent widespread strain of *Puccinia striiformis* f. sp. *tritici* causing stripe rust of wheat. *Phytopathology*, 99(1), 89–94. DOI: 10.1094/PHYTO-99-1-0089.
- Stubbs, R.W. (1985). *The cereal rusts*. Orlando, Florida: Academic Press.
- Sørensen, C.K., Thach, T., & Hovmøller, M.S. (2016). Evaluation of spray and point inoculation methods for the phenotyping of *Puccinia striiformis* on wheat. *Plant Dis.*, 100, 1064–1070. DOI: 10.1094/PDIS-12-15-1477-RE.
- Vallavieille-Pope de, C., Huber, L., Leconte, M., & Goyeau, H. (1995). Comparative effects of temperature and interrupted wet periods on germination, penetration, and infection of *Puccinia recondita* f. sp. *tritici* and *P. striiformis* on wheat seedlings. *Phytopathology*, 85(4), 409–415. DOI: 10.1094/Phyto-85-409.
- Vallavieille-Pope de, C., Huber, L., Leconte, M., & Bethenod, O. (2002). Preinoculation effects of light quantity on infection efficiency of *Puccinia striiformis* and *P. triticina* on wheat seedlings. *Phytopathology*, 92(12), 1308–1314. DOI: 10.1094/PHYTO.2002.92.12.1308.

- Walter, S., Ali, S., Kemen, E., Nazari, K., Bahri, B.A., Enjalbert, J., ... Justesen, A.F. (2016). Molecular markers for tracking the origin and worldwide distribution of invasive strains of *Puccinia striiformis*. *Ecology and Evolution*, 6(9), 2790–2804. DOI: 10.1002/ece3.2069.
- Wan, A.M., & Chen, X.M. (2014). Virulence characterization of *Puccinia striiformis* f. sp. *tritici* using a new set of *Yr* single-gene line differentials in the United States in 2010. *Plant Dis.*, 98(11), 1534–1542. DOI: 10.1094/PDIS-01-14-0071-RE.
- Wang, X.J., Zheng, W.M., Buchenauer, H., Zhao, J., Han, Q.M., Huang, L.L., & Kang, Z.S. (2008). The development of a PCR-based method for detecting *Puccinia striiformis* latent infections in wheat leaves. *European Journal of Plant Pathology*, 120, 241–247. DOI: 10.1007/s10658-007-9212-y.
- Wang, S., Chu, B., Liu, Q., Luo, Y., & Ma, Z. (2017). Development of a sequence-characterized amplified region marker using inter-simple sequence repeats for detection of *Puccinia striiformis* f. sp. *tritici*. *Journal of Phytopathology*, 165(7-8), 442–447. DOI: 10.1111/jph.12578.
- Waqar, A., Khattak, S.H., Begum, S., Rehman, T., Rabia, Shehzad, A., ... Ali, G.M. (2018). Stripe rust: A review of the disease, *Yr* genes and its molecular markers. *Sarhad Journal of Agriculture*, 34(1), 188–201. DOI: 10.17582/journal.sja/2018/34.1.188.201.

OPEN GEO-SPATIAL DATA FOR SUSTAINABLE FOREST MANAGEMENT: LITHUANIAN CASE

***Daiva Tiškutė-Memgaudienė¹, Gintautas Mozgeris¹, Algis Gaižutis²**

¹Vytautas Magnus University, Lithuania

²Forest Owners Association of Lithuania, Vilnius University, Lithuania

*Corresponding author's email: daiva.tiskute-memgaudiene@vdu.lt

Abstract

In Lithuania, forests are managed by Lithuanian State Forest Enterprise, municipalities, ministries, etc. and private forest owners. About 50% of all forest land is State importance, privately owned forests cover 40% of forest land, and about 10% of forest land belongs to forests reserved for restitution. Forest management of private ownership force many challenges, because private forest owners are people, who have purchased or received the property after restitution, and often lacks knowledge about forest resources, its dynamics and sustainable forest management. As remote sensing is a valuable source for forest monitoring, because it provides periodic data on forest resource and condition status, these methods are gaining increased attention worldwide. In this context, more scientific efforts are made at developing remote sensing derived geo-spatial data services for sustainable forest management through a web service platform, which would integrate geo-information into daily decision making processes and operation for private forest owners. This article presents a review of privately owned forests' statistics, questionnaire-based survey about GIS usage and demand for forest owners in Lithuania and links available sources of open geo-spatial data useful for sustainable forest management.

Key words: private forests owners, open geo-spatial data.

Introduction

The importance of providing remote sensing and other geo-spatial data for sustainable forest management is increasing persistently (Pasanen *et al.*, 2005; Kivinen *et al.*, 2008; Store & Antikainen, 2010; Brožová *et al.*, 2020; Shang *et al.*, 2020). Today, forest data and especially remote sensing-derived data can be generated more quickly than we can process it, and it could be integrated into daily decision making processes. Data, provided by the European Union (EU) under the framework of the Copernicus programme, as well as global Earth Observation data from Landsat satellite under joint NASA/USGS program, provides opportunities to wide extent, content and duration land monitoring programs. Operationalization of airborne laser scanning and hyperspectral imaging is also increasing (Wulder *et al.*, 2008; Eysn *et al.*, 2012; Tang & Shao, 2015; Yrtimaa *et al.*, 2020; Tusa *et al.*, 2020). Despite the supply, demand for geo-spatial data remains limited. Even more, limited are the solutions to turn the massive data in-flows into useful geo-spatial information, thus, limited are competences and the needs of potential geo-spatial data users.

In scientific society, efforts of developing and making available sophisticated algorithms for remote sensing data processing, gets more attention (Chen *et al.*, 2020; Mi & Chen, 2020; Sabat-Tomala *et al.*, 2020; Sothe *et al.*, 2020; Zhang *et al.*, 2020). It is hard to expect that average forest stakeholder gets into sophisticated algorithms for remote sensing data processing. Actually, there is no need to understand them, but such algorithms can be implemented into daily decision making process. Thus, there is a potential demand of platform where numerous users could get geo-spatial data-derived solutions without

penetrating into sophisticated technologies of satellite or aircraft-based data collection and processing. Such a platform to be functional, it must be user-oriented. On the other hand, the potential user of the platform needs to understand and know how his/her needs can be met better, cheaper, more efficiently, also be able to think about new needs.

With this study, we aim to review the statistics of privately owned forests in Lithuania and link them with demands for geo-spatial data, bearing in mind the needs of private forestry. We emphasize available open sources of geo-spatial data both at national and the European Union (EU) levels, suitable for solving specific forest management tasks.

Materials and Methods

To review the statistics and spatial pattern of privately owned forests in Lithuania, methods of spatial analysis, descriptive and spatial statistics analysis, utilizing ArcGIS and MS EXCEL software, were used. Due to changes in the state forestry administration system, the inventory of private forest land parcels has changed. Thus, geodatabase of the State Forest Cadastre, available from the State Forest Service, representing the forest cover status on Jan 1, 2017, was used in this study. To evaluate spatial pattern of private, reserved for restitution and other forests cover, the Jenks optimization method was applied. Jenks optimization method is data clustering method, which determines the best arrangement of data values into different classes, minimizing each class's average deviation from the class mean and maximizing each class's deviation from the means of the other groups. The polygons, corresponding to management areas of former state enterprise, were used in the spatial

pattern analysis of private forests cover. A spatial autocorrelation analysis was performed using global Moran's I statistics. Further, Anselin Local Morans index (cluster and outlier analysis) was used to determine which analyzed polygons have significant clustering. As a result of spatial pattern analysis, choropleth map was developed.

In addition, the method of questionnaire was used to collect and evaluate the data of private forest owners' knowledge about geo-spatial data and GIS software usage in Lithuanian private forest sector. This questionnaire was not the main part of this study and just aimed to get acquainted with the situation of GIS usage by private forest owners in Lithuania. Questionnaires were mailed to 80 private forest owner companies. The questionnaire-based survey was conducted in 2019 March – April, in which 31 respondents from 21 municipalities of Lithuania took part.

Finally, we reviewed open geo-spatial data, available at national and EU levels, aiming to simulate the applications related to sustainable forest management. Open geo-spatial data sources were linked to suitability for solving specific forest management task with access using expert evaluation.

Results and Discussions

As reported by official statistics of Lithuania (Source: Official statistics portal), forest land area according to Forest Assessment covered 2189.6 thous. ha of Lithuanian territory in 2017. This means that forests covered 33.5% (Figure 1).

More than half of forest area, i.e. 50.4%, were owned privately or reserved for restitution and 49.6% of forest area was state importance.

The forest cover, within different state forest enterprises boundaries, is clustered (Global Moran's Index 0.617, z-score 5.042, p-value 0.000) (Figure 2).

Privately owned forest cover was discovered to vary from 16.6% to 79.6% in 2017. The modest, i. e. 16.6%, privately owned forest cover was found in the management area of Kazlų Rūda training state forest enterprise (SFE). Slightly larger private forest cover was found in the management area of Dubrava experimental and training SFE (24.5%), Joniškis SFE (25.9%) and Marijampolė SFE (29.9%). Analysis of spatial pattern of private, reserved for restitution and other forests cover, has revealed that in most, i. e. 27, analyzed polygons privately owned forest cover vary from 32.7–55.9%. Largest areas of privately owned forests were found in 11 analyzed polygons, where the private forest cover varied from 58.5% in the management area of Tytuvėnai SFE to 71.1% in the management area of Zarasai SFE and even 79.6% in the management area of Utena SFE. Such high percent of privately owned forest in the management area of Zarasai SFE and the management area of Utena SFE, could be determined by relief with predominated lake landscape and high demand of forests encompassing recreational use. Despite enlarged private forest cover, because of recreational demand in Utena and Zarasai districts, results of analysis of privately owned forest cover distribution in Lithuania ascertains that private forest estates cover large area of Lithuania territory,

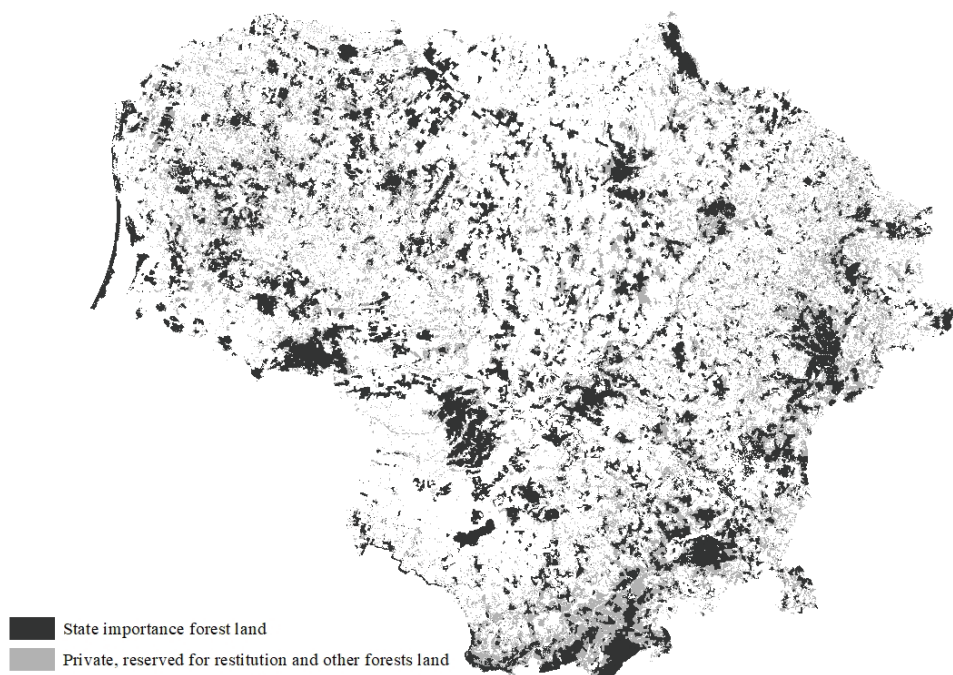


Figure 1. Lithuanian forests by ownership types in Lithuania (Source: State Forest Cadastre, 2017).

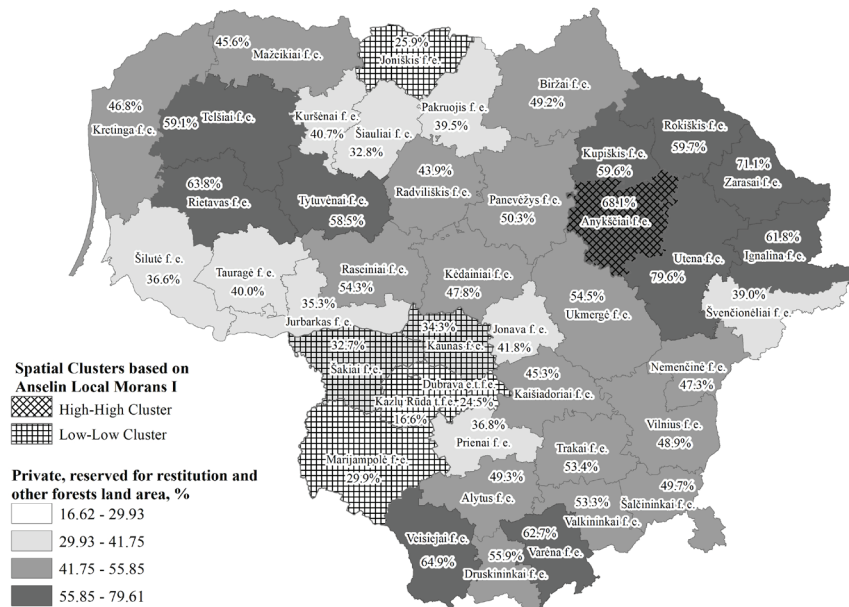


Figure 2. Spatial pattern of private, reserved for restitution and other forests (i.e. not the forests of state importance), within state forest enterprises boundaries, in Lithuania.

involving lots of private owners with more or less, or even no knowledge about forestry and sustainable forest management.

The questionnaire-based survey has indicated that just 32% of private forest companies used GIS technology in the daily professional activities. 20% of the respondents, if needed, bought GIS services and 10% of respondents planned to start using GIS in coming 3 years. Private forest owners used two different software for geo-spatial data analysis and mapping, e. g. commercial software ArcGIS (60%) and open source software QGIS (40%). The following reasons why GIS was not used by private forest owners, where listed: lack of demand (44%), high hardware and software costs (41%), lack of professional GIS users in private forest sector (9%), lack of geo-spatial data (6%). The questionnaire-based survey ascertains that usage of geo-spatial data as well as software for such data processing is fragmented among private forest owners in Lithuania. As it could be foreknown, private forest owners, who manage about half of Lithuania forests, lack innovative, thus sustainable, instruments and data in their daily decision-making activities and long-term strategical process.

Further study has revealed, that there is lots of open geo-spatial data sources covering Lithuania territory and providing data for forest inventory and management, starting with Georeference spatial data set of the territory of the Republic of Lithuania at scale 1:250 000 according to the requirements of the international project EuroRegionalMap and Spatial data set of (geo) reference base cadastre (GRPK),

continuing with additional data for forest management as Data of state cadastre for protected areas of Lithuania, Bogs and peatlands of Lithuania, Natural habitats of EU importance, General restrictions of forest management in NATURA 2000 sites, etc. and ending with key data for forest management as Forest cadastre of Lithuania where data about forest management plans in private and state forests, forest's conditions after natural events (fires, windstorms), forest compartments, land utilities, etc. are provided. Moreover, some data is provided in different data formats which are used for both – open source software as QGIS, e. g. GML and commercial software as ArcGIS, e. g. ESRI FileGeodatabase, ESRI Shape, etc. In addition, users of this portal can use not only Inspire download service (WFS), but also Inspire view service (WMS) – both types of services are standardized by Open Geospatial Consortium (OGC) (Table 1).

Main open geo-spatial information providing data about land cover as well as forests at European Union level can be accessed by European Environment Agency (EEA) under the framework of the Copernicus programme. Some iterative open geo-spatial data adjusted for Lithuania territory can be found in geoportal of Lithuania (Table 2).

Remote sensing and forest management has long been associated in Lithuania only in the context of forest inventory related application (Bikuvienė & Tiškutė-Memgaidienė, 2016; Mozgeris, 2008; Mozgeris *et al.*, 2008). Stand-wise forest inventories were completely based on application of orthophotos,

Table 1

Open geo-spatial data available at national level

Name of open geo-spatial data	Service type in geoportal.lt	Author	Data format	Forest management tasks the data could be used for
Forest cadastre data	Dataset, Inspire view service, Inspire download service	State Forest Survey service under the Ministry of Environment	ESRI shape, WMS, WFS	1, 2, 4–20*
Boundaries of state forest areas	Inspire view service, Inspire download service	State Forest Survey service under the Ministry of Environment	WMS, WFS	1, 2*
The high resolution layer of forest	Dataset	Environmental Protection Agency	TIFF	9, 11, 14, 15*
Natural habitats of EU importance	Dataset, Inspire view service	The Institute of Botany of Nature Research Centre	ESRI FileGeodatabase, ESRI Shape, etc., WMS	2, 5, 6, 11, 16–19*
Natural habitats of EU importance (boundaries)	Inspire view service	The Institute of Botany of Nature Research Centre	WMS	2, 5, 6, 11, 16–19*
Natural habitats of EU importance	Dataset	SE GIS-Centras	GML	2, 5, 6, 11, 16–19*
Bogs and peatlands of Lithuania (2018 evaluation by LFN)	Inspire view service	Lithuanian Fund for Nature	WMS	2, 9, 11–15*
GRPK – Spatial data set of (geo) reference base cadastre	Inspire view service, Inspire download service	Ministry of Agriculture of the Republic of Lithuania	WMS, WFS	1, 2, 7–20*
GRPK – Spatial data set of (geo) reference base cadastre (static)	Dataset	Ministry of Agriculture of the Republic of Lithuania	ESRI FileGeodatabase, ESRI Shape, etc.	1, 2, 7–20*
GRPK – Spatial data set of (geo) reference base cadastre (dynamic)	Dataset	Ministry of Agriculture of the Republic of Lithuania	ESRI FileGeodatabase, ESRI Shape, etc.	1, 2, 7–20*
GRPK map – Georeferential Base Map at Scale 1:10 000	Other Services	Ministry of Agriculture of the Republic of Lithuania	PDF	1, 2, 7–20*
ERM_250LT – georeference spatial data set of the territory of the Republic of Lithuania at scale 1:250 000 according to the requirements of the international project EuroRegionalMap	Dataset, Inspire view service	National Land Service under the Ministry of Agriculture	ESRI File Geodatabase, WMS	9–14, 20*
View service of Free State Land Fund data	Inspire view service	National Land Service under the Ministry of Agriculture	WMS	14, 17, 18*
Free State land fund information interactive electronic service	Inspire view service	National Land Service under the Ministry of Agriculture	WMS	14, 17, 18*

Name of open geo-spatial data	Service type in geoportal.lt	Author	Data format	Forest management tasks the data could be used for
The National atlas of the Republic of Lithuania in digital format. Forests	Inspire view service	National Land Service under the Ministry of Agriculture	WMS	9–11, 14, 15, 20*
The National atlas of the Republic of Lithuania in digital format. Forest density	Inspire view service	National Land Service under the Ministry of Agriculture	WMS	9–11, 14, 15, 20*
General restrictions of forest management in NATURA 2000 sites	Inspire view service	State service for protected areas under the Ministry of Environment	WMS	1, 2, 4–6, 9, 11–13, 15, 16–18*
Data of State Cadastre for Protected Areas of Lithuania	Dataset, Inspire view service	State service for protected areas under the Ministry of Environment	ESRI FileGeodatabase, ESRI Shape, etc., WMS	1, 2, 4–20*
Land Parcel Identification System (KZS) Database	Dataset	SE GIS-Centras	GML	11, 14, 15, 18*
Data Base of Limited Land Use Areas of the Republic of Lithuania at scale 1:10 000 SŽNS_DR10LT	Dataset, Inspire view service	National Land Service under the Ministry of Agriculture	ESRI FileGeodatabase, WMS	1, 2, 4–20*
Data Base of Limited Land Use Areas of the Republic of Lithuania at scale 1:10 000 SŽNS_DR10LT (dynamically updated) SŽNS_DR10LT	Dataset	National Land Service under the Ministry of Agriculture	ESRI Shape	1, 2, 4–20*
Data Base of Limited Land Use Areas of the Republic of Lithuania at scale 1:10 000 SŽNS_DR10LT	Dataset	SE GIS-Centras	GML	1, 2, 4–20*

*1 – forest inventory; 2 – forest management planning; 3 – monitoring of silviculture activities; 4 – afforestation/reforestation planning; 5 – final harvesting planning; 6 – thinning planning; 7 – forest logistics; 8 – forest fire protection; 9 – environment protection; 10 – recreation planning; 11 – biodiversity assessment; 12 – wildlife management; 13 – game management; 14 – land use change monitoring; 15 – wetland management; 16 – economic evaluation; 17 – real estate management; 18 – EU subsidies management; 19 – pest control; 20 – historical heritage.

while the National forest inventory by sampling methods utilized also some alternative sources of remotely sensed information, including satellite images (Kasperavičius *et al.*, 2000). The procurement of stand-wise forest inventories in the country was mainly associated with the update of the Forest State Cadaster, and the inventories were implemented on a 10-years cycle for all forests in the country, i.e. no matter the ownership. However, the reform in administration of state forests in Lithuania which took place in 2018 (Makrickiene *et al.*, 2019) resulted in stopping unified and state paid stand-wise inventories in the private forests. Nevertheless, to implement forest management activities, all forest owners are required to have valid forest management plans, preceded by field inventories, implemented usually by numerous individual forest inventory engineers.

It is obvious, that the private forest owner possessing several hectares of forest may not pay for remotely sensed data acquisition missions, even though they are very cheap solution based on e.g. the use of unmanned aviation vehicles or ultra-light aviation (Mozgeris & Augustaitis, 2013; Mozgeris *et al.*, 2018a; Mozgeris *et al.*, 2018b). Thus, availability of open source data opens additional opportunities for private forest inventories and management planning, even though the data may be not perfectly emulating the conventional orthophotos.

Nowadays, management of private forests in Lithuania does not necessary include aiming for profits, usually arriving from timber harvesting (Stanislovaitis *et al.*, 2015). In that context, we see additional uses of open data sources for tasks currently not considered widely in current forest

Table 2

Open geo-spatial data available at EU level

Name of open geo-spatial data	Resource type	Author	Data format	Spatial resolution, m	Forest management tasks the data could be used for *
CORINE land cover (CLC) 1995	Dataset, Inspire view service, Inspire download service	Environmental Protection Agency	ESRI File Geodatabase, ESRI Personal Geodatabase, ESRI Shape, WMS, WFS	-	9–15, 19*
CORINE land cover (CLC) 2000					
CORINE land cover (CLC) 2006					
CORINE land cover (CLC) 2012					
CORINE land cover (CLC) 2018	Dataset, Inspire view service		ESRI File Geodatabase, ESRI Personal Geodatabase, ESRI Shape, WMS		
CORINE land cover change (CHA) 1995–2000	Dataset, Inspire view service, Inspire download service	Environmental Protection Agency	ESRI File Geodatabase, ESRI Personal Geodatabase, ESRI Shape, WMS, WFS	-	9–15, 19*
CORINE land cover change (CHA) 2000–2006					
CORINE land cover change (CHA) 2006–2012	Dataset, Inspire view service		ESRI File Geodatabase, ESRI Personal Geodatabase, ESRI Shape, WMS		
CORINE land cover (CLC) 1990	Dataset	European Environment Agency	ESRI Geodatabase, SQLite Database, GeoTIFF	100	9–15, 19*
CORINE land cover (CLC) 2000					
CORINE land cover (CLC) 2006					
CORINE land cover (CLC) 2012					
CORINE land cover (CLC) 2018					
CORINE land cover change (CHA) 1990–2000					
CORINE land cover change (CHA) 2000–2006					
CORINE land cover change (CHA) 2006–2012					
CH CORINE land cover change (CHA) A 2012–2018					
Tree Cover Density 2012	Dataset	European Environment Agency	GeoTIFF	20	9–11, 14, 15, 20*
Tree Cover Density 2015					

Name of open geo-spatial data	Resource type	Author	Data format	Spatial resolution, m	Forest management tasks the data could be used for *
Tree Cover Density Change 2012–2015	Dataset	European Environment Agency	GeoTIFF	100	9–11, 14, 15, 20*
Dominant Leaf Type 2012	Dataset	European Environment Agency	GeoTIFF	20	8, 9, 11, 12, 14, 15, 19*
Dominant Leaf Type 2015					
Forest Type 2012	Dataset	European Environment Agency	GeoTIFF	20, 100	8, 9, 11, 12, 14, 15, 19*
Forest Type 2015					
Forest Additional Support Layer 2012	Dataset	European Environment Agency	GeoTIFF	20	3, 8, 9, 11, 12, 14, 15, 19*
Forest Additional Support Layer 2015					

*1 – forest inventory; 2 – forest management planning; 3 – monitoring of silviculture activities; 4 – afforestation/reforestation planning; 5 – final harvesting planning; 6 – thinning planning; 7 – forest logistics; 8 – forest fire protection; 9 – environment protection; 10 – recreation planning; 11 – biodiversity assessment; 12 – wildlife management; 13 – game management; 14 – land use change monitoring; 15 – wetland management; 16 – economic evaluation; 17 – real estate management; 18 – EU subsidies management; 19 – pest control; 20 – historical heritage.

management practices. Such data may become a corner stone to develop and introduce a cost and time efficient solution for permanent monitoring of private (or all forests no matter the ownership) forests, including detection of natural and human induced changes, permanent updating data required for stand-wise forest inventories, supporting improved forest management decisions and advice. Obviously, historical information on the conditions of forest resources is a prerequisite to start monitor the development. Moreover, using open GIS data sets provide more information needed to quantify other forest ecosystem services and conduct the monitoring of them in Lithuanian private forest estates, e.g. the carbon balance, regulatory forest services, including reduced mortality risks due to wind, insects or diseases or providing habitats for forest dwelling species (Bāders *et al.*, 2018a; Bāders *et al.*, 2018b; Treinys *et al.*, 2016).

Available datasets seem to cover large diversity of needs for sustainable management of private forests in Lithuania. Thus, availability of data may hardly be considered as the factor restricting progress of geo-spatial technologies in private forestry in Lithuania. This is also confirmed by relatively low share (6%) of respondents, thinking that geo-spatial technologies are purely used in private forest sector because of geo-spatial data lack. Therefore, we explain the relatively low level of GIS utilization in private forest management in the country by limited needs for taking

of enhanced management decisions. We explain this also by strong impacts of command and control forest management, inherited from the planned economy (Makrickiene *et al.*, 2019).

Conclusions and Proposals

Although privately owned forests cover about half of forest area in Lithuania, slightly small part of private forest owners used GIS technology in their daily professional activities. The list of reasons why GIS technologies were not used by private forest owners is as follows: lack of demand (44%), high hardware and software costs (41%), lack of professional GIS users in private forest sector (9%), lack of geo-spatial data (6%). But our study indicated that available open geospatial data covers a large diversity of needs for sustainable management of private forests in Lithuania. GIS technologies could be evolved to an integrated and flexible system, used in all stages of forest inventory, management and control not only in state, but also in private forestry. There is no limitation to implement innovative solutions based on geo-spatial information into sustainable forest management for private forest owners.

Acknowledgements

This study has been implemented in the context of the European Union’s Horizon 2020 research and innovation programme under the grant agreement No. 776045. <https://mysustainableforest.com>.

References

- Bādērs, E., Jānsons, Ā., Matisons, R., Elferts, D., & Desaine, I. (2018a). Landscape diversity for reduced risk of insect damage: a case study of Spruce bud Scale in Latvia. *Forests*, 9, 545. DOI: 10.3390/f9090545.
- Bādērs, E., Lūkins, M., Zariņš, J., Krišāns, O., Jānsons, Ā., & Jānsons, J. (2018b). Recent land cover changes in Latvia. *Proceedings of 24th Annual International Scientific Conference 'Research for Rural Development 2018'*. 1, 34–39. DOI: 10.22616/RRD.24.2018.005.
- Bikuvienė, I., & Tiškutė-Memgaidienė, D. (2016). GIS in Lithuanian forest inventory – 20 years' experience. *Sinteza 2016 – International Scientific Conference on ICT and E-Business Related Research*. 208–212. DOI: 10.15308/Sinteza-2016-208-212.
- Brožová, N., Fischer, J.-T., Bühler, Y., Bartelt, P., & Bebi, P. (2020). Determining forest parameters for avalanche simulation using remote sensing data. *Cold Regions Science and Technology*. 172. DOI: 10.1016/j.coldregions.2019.102976.
- Chen, D., Loboda, T.V., & Hall, J.V. (2020). A systematic evaluation of influence of image selection process on remote sensing-based burn severity indices in North American boreal forest and tundra ecosystems. *ISPRS Journal of Photogrammetry and Remote Sensing*. 159, 63–77. DOI: 10.1016/j.isprsjprs.2019.11.011.
- Eysn, L., Hollaus, M., Schadauer, K., & Pfeifer, N. (2012). Forest Delineation Based on Airborne LIDAR Data. *Remote Sensing*. 4(3), 762–783. DOI: 10.3390/rs4030762.
- Kasperavičius, A., Kuliešis, A., & Mozgeris, G. (2000). Satellite imagery based forest resource information and its application for designing the national forest inventory in Lithuania. *Conference on remote sensing and forest monitoring proceedings*. 50–58.
- Kivinen, S., Koivisto, E., Keski-Saaria, S., Poikolainen, L., Tanhuanpää, T., Kuzmin, K., Viinikka, A., Heikkinen, R.K., Pykälä, J., Virkkala, R., Vihervaara, P., & Kumpula, T. (2020). A keystone species, European aspen (*Populus tremula* L.), in boreal forests: Ecological role, knowledge needs and mapping using remote sensing. *Forest Ecology and Management*. 462. DOI: 10.1016/j.foreco.2020.118008.
- Makrickienė, E., Brukas, V., Brodrechtova, Y., Mozgeris, G., Sedmák, R., & Šálka, J. (2019). From command-and-control to good forest governance: A critical interpretive analysis of Lithuania and Slovakia. *Forest Policy and Economics*. 109. DOI: 10.1016/j.forpol.2019.102024.
- Mi, L., & Chen, Z. (2020). Superpixel-enhanced deep neural forest for remote sensing image semantic segmentation. *ISPRS Journal of Photogrammetry and Remote Sensing*. 159, 140–152. DOI: 10.1016/j.isprsjprs.2019.11.006.
- Mozgeris, G. (2008). Estimation and use of continuous surfaces of forest parameters: Options for Lithuanian forest inventory. *Baltic Forestry*. 14(2), 176–184.
- Mozgeris, G., Galaunė, A., & Palicinas, M. (2008). Systemy informacji geograficznej w zarządzaniu lasu na Litwie – dekada praktycznego stosowania (Geographical information systems in forest management planning in Lithuania – a decade of practical application). *Sylwan*. 152(1), 58–63. (in Polish).
- Mozgeris, G., & Augustaitis, A. (2013). Estimating crown defoliation of Scots pine (*Pinus sylvestris* L.) trees using small format digital aerial images. *iForest-Biogeosciences and Forestry*. 6 (1), 15–22. DOI: 10.3832/ifer0705-006.
- Mozgeris, G., Jonikavičius, D., Jovarauskas, D., Zinkevičius, R., Petkevičius, S., & Steponavičius, D. (2018a). Imaging from manned ultra-light and unmanned aerial vehicles for estimating properties of spring wheat. *Precision Agriculture*. 19(5), 876–894. DOI: 10.1007/s11119-018-9562-9.
- Mozgeris, G., Juodkienė, V., Jonikavičius, D., Straigytė, L., Gadal, S., & Ouerghemmi, W. (2018b). Ultra-Light Aircraft-Based Hyperspectral and Colour-Infrared Imaging to Identify Deciduous Tree Species in an Urban Environment. *Remote sensing*. 10(10), 1–22. DOI: 10.3390/rs10101668.
- Official statistics portal Retrieved January 12, 2020, from <http://osp.stat.gov.lt/en/statistiniu-rodikliu-analize?portletFormName=visualization&hash=3f0702fa-845f-42cd-9a58-8786bbfc507c>.
- Pasanen, K., Kurttila, M., Pykäiäinen, J., Kangas, J., & Leskinen, P. (2005). Mesta – non evaluation of alternative forest plans over the Internet. *International Journal of Information Technology & Decision Making*. 04(04), 601–620. DOI: 10.1142/S0219622005001726.
- Sabat-Tomala, A., Raczko, E., & Zagajewski, B. (2020). Comparison of Support Vector Machine and Random Forest Algorithms for Invasive and Expansive Species Classification Using Airborne Hyperspectral Data. *Remote Sensing*. 12(3), 516. DOI: 10.3390/rs12030516.
- Shang, C., Coops, N.C., Wulder, M.A., White, J.C., & Hermosilla, T. (2020). Update and spatial extension of strategic forest inventories using time series remote sensing and modeling. *International Journal of Applied Earth Observation and Geoinformation*. 84. DOI: 10.1016/j.jag.2019.101956.

- Sothe, C., De Almeida, C.M., Schimalski, M.B., Liesenberg, V., La Rosa, L.E.C., Castro, J.D.B., & Feitosa, R.Q. (2020). A comparison of machine and deep-learning algorithms applied to multisource data for a subtropical forest area classification. *International Journal of Remote Sensing*. 41(5), 1943–1969. DOI: 10.1080/01431161.2019.1681600.
- Stanislovaitis, A., Brukas, V., Kavaliauskas, M., & Mozgeris, G. (2015). Forest owner is more than her goal: a qualitative typology of Lithuanian owners. *Scandinavian Journal of Forest Research*. 30(5), 478–491. DOI: 10.1080/02827581.2014.998706.
- Store, R., & Antikainen, H. (2010). Using GIS-based multicriteria evaluation and path optimization for effective forest field inventory. *Computers, Environment and Urban Systems*. 34(2), 153–161. DOI: 10.1016/j.compenurbsys.2009.12.003.
- Tang, L., & Shao, G. (2015). Drone remote sensing for forestry research and practice. *Journal of forestry research*. 26, 791–797.
- Tusa, E., Laybros, A., Monnet, J.-M., Mura, M.D., Barré, J.-B., Vincent, G., Dalponte, M., Féret, J.-B., & Chanussot, J. (2020). Fusion of hyperspectral imaging and LiDAR for forest monitoring. *Data Handling in Science and Technology*. 32, 281–303. DOI: 10.1016/B978-0-444-63977-6.00013-4.
- Treinyš, R., Mozgeris, G., & Skuja, S. (2016). Can intensified forestry be responsible for changes in habitat usage by the forest-dwelling Black Stork? *European Journal of Forest Research*. 135, 1175–1186. DOI: 10.1007/s10342-016-1003-6.
- Wulder, M.A., Bater, C.W., Coops, N.C., Hilker, T., & White, J.C. (2008). The role of LiDAR in sustainable forest management. *The Forestry Chronicle*. 84(6), 807–826. DOI: 10.5558/tfc84807-6.
- Yrttimaa, T., Saarinen, N., Luoma, V., Tanhuanpää, T., Kankare, V., Liang, X., Hyypä, J., Holopainen, M., & Vastaranta, M. (2020). Terrestrial Laser Scanning and Ground Truth Data for Characterizing Downed Dead Wood. OSF. DOI: <https://osf.io/rjegd/>.
- Zhang, J., Hu, X., Dai, H., & Qu, S.R. (2020). DEM Extraction from ALS Point Clouds in Forest Areas via Graph Convolution Network. *Remote Sensing*. 12(1), 178. DOI: 10.3390/rs12010178.

INFLUENCE OF DRAINAGE RECONSTRUCTION ON RADIAL INCREMENT OF CONIFERS: CASE STUDY

*Baiba Jansone^{1,2}, Linards Sisenis¹, Irina Pilvere¹, Marcis Vinters¹, Karlis Bickovskis²

¹Latvia University of Life Sciences and Technologies, Latvia

²Latvian State Forest Research Institute 'Silava', Latvia

*Corresponding author's email: baiba.jansone@llu.lv

Abstract

Drainage ensures flow of water and access of oxygen to the roots of the trees. Therefore, melioration systems have been established in a third of the forest area of Latvia, and for the most part highly productive stands can be observed in these areas. Water flow in these systems is often stopped by beaver dams. The aim of our case study was to assess the impact of ditch reconstruction on the increment of the coniferous trees. Increment cores were collected from 169 trees at a distance up to 45 m from the ditch in the drainage system that was reconstructed 8 years prior.

Drainage system reconstruction reversed the trend of declining radial increment for both Scots pine and Norway spruce; however, the influence of this measure over an 8 year period was statistically significant, notable (55%) and positive only for Norway spruce, growing closest to the edge of the ditch. Other growth limiting factors need to be considered and tackled to ensure the highest effect of the investment in drainage system reconstruction, including choice of the tree species, stand density, age, availability of nutrients.

Key words: ditch, *Picea abies*, forest management, growth response, growth release.

Introduction

Drainage (melioration) has been the most important factor, increasing forest productivity in Latvia over the last half a century. Notable share (32%, based on National Forest Inventory data) of our forests currently are located on drained soils. Additionally, increased growth (current annual increment) had attributed to Climate change (Pretzsch *et al.*, 2014). This effect, however, differs between tree species, and has been notable for Norway spruce (*Picea abies* (L.) Karst.) already at young (up to 40 years) age (Pretzsch *et al.*, 2014). Similarly, a relatively long-lasting influence of fertilization, has been observed of the tree species (Jansons *et al.*, 2016a). The increment (productivity) of the trees can be even further raised by influence of climate in combination with changes in silviculture e.g., tailored soil preparation, tending, different stand density (Dzerina *et al.*, 2016; Celma *et al.*, 2018; Katrevičs *et al.*, 2018; Katrevičs *et al.*, 2018). Also, application of tree breeding results, currently a very common practice for Scots pine (mostly planted, all plants grown from seed orchard seeds) and Norway spruce (almost exclusively planted, most of plants form seed orchard seeds), can substantially increase the growth (Jansons, Gailis, & Donis, 2011; Jansons *et al.*, 2015a). Increase in stem volume growth of at least 10% by selecting a seed source can be achieved (Janson *et al.*, 2013), as well as increased the above-ground biomass (Lībiete-Zālīte & Jansons, 2011; Lībiete *et al.*, 2017); these figures are affected by genotype-environment interaction (Janosns *et al.*, 2008). Relative high realized gain values are especially true if vegetatively propagated material is used in regeneration (Zeltiņš *et al.*, 2018b). The use of improved material does not lead to notable reduction of genetic diversity (Runģis *et al.*, 2019). However,

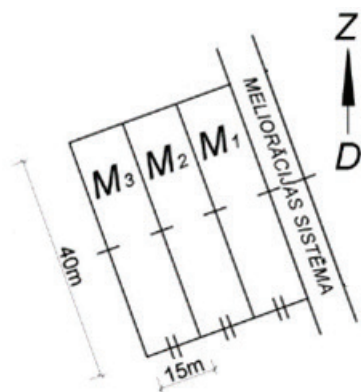
careful selection of clones not only by growth, but also by resistance is essential to ensure a good outcome of valuable assortments and minimize the potential negative influence of Climate change (Zeltins *et al.*, 2016, 2018a). Ongoing changes in climate, as predicted currently, might lead to limits of phenotypic plasticity of trees (Schmidt-Vogt, 1977). Limiting factors, like summer drought (Jansons *et al.*, 2015b; Matisons *et al.*, 2017) might have increasingly more influence on the total increment. Also, increasingly favourable conditions for dendrophagous insects (Bāders *et al.*, 2018) can lead to larger areas of low survival and/or growth of forests. Selection of robust seed sources (provenances), suitable for respective conditions and fast growth might be part of the solution (Rieksts-Riekstins *et al.*, 2014; Matisons *et al.*, 2018).

In Europe, damages in forests are caused by fires, wind storms and bark beetles (Seidl *et al.*, 2014; Kitenberga *et al.*, 2018, 2019). However, in the areas with excess water due to precipitation or ground water regime (usually the case in Latvia) is also a growth limiting factor to a large extent. All of these factors can be at least to some extent influenced by behavior change or management activities (Donis *et al.*, 2017). Water regime is relatively difficult to change, and it requires a significant financial investment. Therefore, assessment of the potential gain (revenue) in terms of additional tree growth is important to ensure, that the additional value, planed by this activity, can actually be achieved.

The aim of our case study was to assess the impact of ditch reconstruction on the increment of the coniferous trees.

Materials and Methods

Data were collected in the central part of Latvia, in the mild (maritime) climatic conditions – in this region



MELIORĀCIJAS SISTĒMA – element of drainage system – ditch

Figure 1. Allocation of sample plots.

30-years mean air temperature in July and January was +18 and -6 °C, respectively. Frost-free period was 140 days on average; annual sum of precipitation varies between 700 and 800 mm. Relief is generally flat, low elevation above the sea level, thus the maintenance of drainage system is important to ensure water flow.

In the forest type with fertile drained peat soil (*Myrtillosa turf. mel.*), sample plots were placed systematically, parallel to the ditch, in different distances from it (Figure 1). In this forest type, peat consists primarily from the elements of trees and vascular plants.

Mixed stand, including Scots pine and Norway spruce in similar proportions (in M1 and M2) and admixture of birch (in M3) were selected. Drainage system was established in 1981 and cleaned, mainly from the beaver dams, blocking the water flow (reconstructed) in 2010.

All trees were measured (height and diameter at breast height – DBH). Increment cores were collected from the breast height from altogether 169 trees,

randomly selected from different diameter classes. Cores were sanded and increments measured with LINTAB.

Results and Discussion

Mean height and DBH was similar for both coniferous tree species with slightly higher values of Scots pine. Height ranged from 20.1±0.7 m (here and further in text: ±95% confidence interval) to 21.4±0.6 m for spruce and from 20.6±0.6 m to 23.6±0.6 m for pine; respective figures for DBH were from 19.5±1.6 cm to 22.9±3.9 cm and from 23.0±2.3 cm to 24.4±1.9 cm. The mean breast height age for both coniferous tree species was 56 years.

Notable reaction to the reconstruction of drainage system – thus the availability of the oxygen to the root system of trees – can be observed for Scots pine and Norway spruce (Figures 2, 3). Even so, for Scots pine the reaction was pronounced only in the area close to the ditch (M1) and not long-lasting; after a few years the on-going downward trend of the annual ring-width

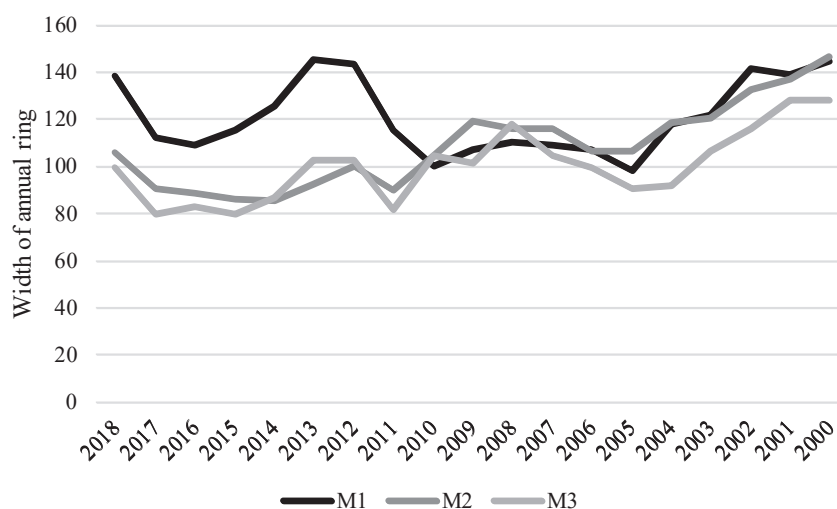


Figure 2. Changes in annual ring width for Scots pine.

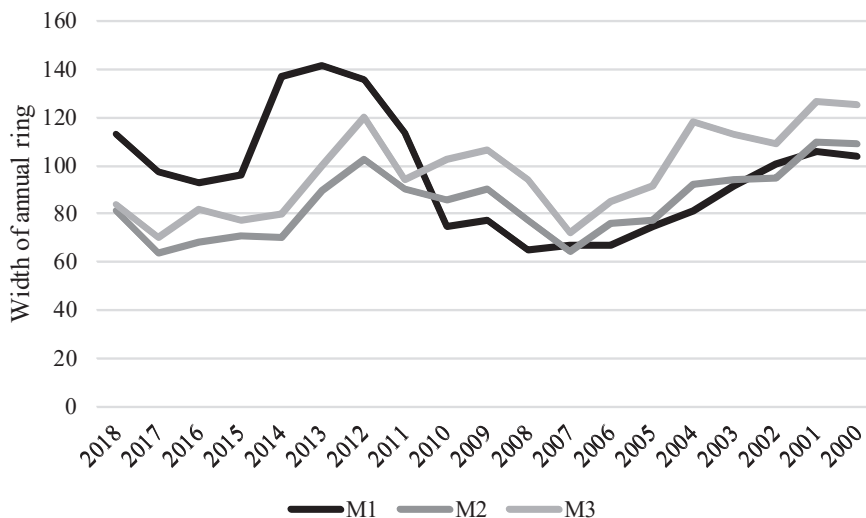


Figure 3. Changes in annual ring width for Norway spruce.

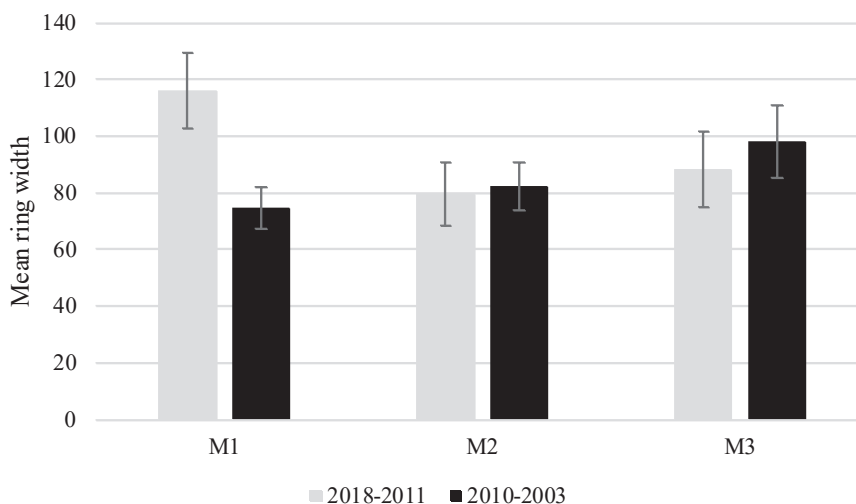


Figure 4. Mean annual ring width for Norway spruce.

continued. Presumably, it might be the result of rather high stand density – basal area reaching 37–41 m² ha⁻¹ in M2 and M3, and 28 m² ha⁻¹ in M1. Stand density is a significant factor, affecting the increment of trees for a long period of time: initially sparse stands have notably larger DBH than dense even at the age of c.a. 50 years (Katrevičs *et al.*, 2018). It is at least partly related to the development of the green crown – thus the capacity of production of organic matter. Pruning experiments had clearly demonstrated that the removal of lower branches from the green crown have no negative impact on the radial increment (Baders *et al.*, 2017); however, the length of the green crown has.

In such a high density the radial increment of trees, especially of light demanding ones (pine), was negatively affected. It could explain, why for this tree species the mean ring width in an 8 – year interval prior to drainage system reconstruction (year 2003–

2010) was not significantly different than in an 8 – year interval (years 2011–2018) after it.

Norway spruce also demonstrated rather sharp rise of the increment after drainage system reconstruction, followed by a few years of its drop. However, the comparison of mean annual ring width over a longer period of time before and after the drainage system reconstruction clearly demonstrates that closer to the ditch statistically significant, notable (by 55%) increase occurred (Figure 4). It might be both related to the shade tolerance (also higher density stand trees react to the improved conditions) as well as to higher sensitivity to excess water for Norway spruce. Such sensitivity had been demonstrated both for radial (Jansons *et al.*, 2016b) and height increment for trees at different age, including on formation of lammas growth at the end of the vegetation season (Katrevičs *et al.*, 2018).

The observed relative weak influence from the investment in the drainage system reconstruction might be also related to the age related trend (Jansons *et al.*, 2016b). Also, lack of mineral elements to some extent might be contributing – it has been shown, that even a single initial fertilization has long (up to 15 years) lasting positive influence on the radial increment of Norway spruce (Jansons *et al.*, 2016a).

Relative stand density reached 0.8 in the M1 and 1.1 in the M2 and M3. Even though the tree diameter was not significantly affected before the drainage system reconstruction (mean diameter was not significantly different), the trees might be able to react to improved conditions. In the high density stands trees, especially of the light demanding species, they tend to lose the green crown rapidly. Even after the conditions improvement (after the thinning or natural disturbance e.g. windstorm), there is not sufficient amount of foliage for rapid response and growth of stem. Besides, trees in such conditions after release might be unstable (Donis *et al.*, 2018), thus allocating more of the resource to root growth than to above-ground growth. Tree reaction to the drainage system reconstruction might be limited

also due to un-visible under-ground water flow also in seemingly over-grown ditches. However, such flow would be stopped by the beaver dams.

Conclusions

1. Drainage system reconstruction reversed the trend of declining radial increment (presumably related to tree age and stand density) for both Scots pine and Norway spruce.
2. Influence of this measure over a longer period of time (8 years) was statistically significant and positive for Norway spruce, growing close to the edge of the ditch.
3. To ensure the highest effect of the investment in drainage system reconstruction, it needs to be combined with other forest management measures, aimed at different growth-limiting factors, e.g. thinning.

Acknowledgements

The study was supported by LLU project ‘Assessment of the influence of beaver created rise of water level on productivity of forest stands’.

References

- Baders, E., Donis, J., Snepsts, G., Adamovics, A., & Jansons, A. (2017). Pruning effect on Norway spruce (*Picea abies* (L.) Karst.) growth and quality. *Forestry Studies*, 66, 33–48.
- Bādērs, E., Jansons, Ā., Matisons, R., Elferts, D., & Desaine, I. (2018). Landscape diversity for reduced risk of insect damage: a case study of Spruce bud Scale in Latvia. *Forests*, 9, 545; DOI: 10.3390/f9090545.
- Celma, S., Blate, K., Lazdiņa, D., Dūmiņš, K., Neimane, S., Štāls, T.A., & Štikāne, K. (2018). Effect of soil preparation method on root development of *P. sylvestris* and *P. abies* saplings in commercial forest stands. *New Forests*, 50 (2), 283–289. DOI: 10.1007/s11056-018-9654-4.
- Donis, J., Kitenberga, M., Snepsts, G., Dubrovskis, E., & Jansons, A. (2018). Factors affecting windstorm damage at the stand level in hemiboreal forests in Latvia: case study of 2005 winter storm. *Silva Fennica*. Vol. 52 No. 4 article id 10009. DOI: 10.14214/sf.10009.
- Donis, J., Kitenberga, M., Snepsts, G., Matisons, R., Zarins, J., & Jansons, A. (2017). The forest fire regime in Latvia during 1922–2014. *Silva Fennica*, 51 (5), DOI: 10.14214/sf.7746.
- Dzerina, B., Girdziusas, S., Lazdina, D., Lazdins, A., Jansons, J., Neimane, U., & Jansons, Ā. (2016). Influence of spot mounding on height growth and tending of Norway spruce: case study in Latvia. *Forestry Studies*, 65, 24–33. DOI: 10.1515/fsmu-2016-0009.
- Haapanen, M., Jansson, G., Nielsen, U.B., Steffenrem, A., & Stener, L.G. (2015). The status of tree breeding and its potential for improving biomass production: A review of breeding activities and genetic gains in Scandinavia and Finland. Uppsala: Skogforsk.
- Jansons, Ā. (2008). Genotype-environment interaction in Latvian Scots pine growth and quality traits and its impact to progeny testing. In: Z. Gaile (ed.) Proceeding of international scientific conference Research for Rural Development, 21–23 of May 2008 (pp. 128–136). Jelgava, Latvija: LLU.
- Jansons, Ā., Gailis, A., & Donis, J. (2011). Profitability of silver birch (*Betula pendula* Roth.) breeding in Latvia. In: Z. Gaile (ed.) Proceedings of the 17th international scientific conference Research for Rural Development, 18–20 May 2011 (pp. 33.–38). Jelgava, Latvia: LLU.
- Jansons, A., Donis, J., Danusevičius, D., & Baumanis, I. (2015a). Differential analysis for next breeding cycle for Norway spruce in Latvia. *Baltic Forestry*, 21(2), 285–297.
- Jansons, Ā., Matisons, R., Zadiņa, M., Sisenis, L., & Jansons, J. (2015b). The effect of climatic factors on height increment of Scots pine in sites differing by continentality in Latvia. *Silva Fennica*, 49 (3), 14p.
- Jansons, Ā., Matisons, R., Krišāns, O., Džeriņa, B., & Zeps, M. (2016a). Effect of initial fertilization on 34-year increment and wood properties of Norway spruce in Latvia. *Silva Fennica*, 50 (1), 8 p. DOI: 10.14214/sf.1346.

- Jansons, Ā., Matisons, R., Šēnhofa, S., Katrevičs, J., & Jansons, J. (2016b). High-frequency variation of tree-ring width of some native and alien tree species in Latvia during the period 1965–2009. *Dendrochronologia*, 40, 151–158.
- Jansson, G., Danusevičius, D., Grotehusman, H., Kowalczyk, J., Krajmerova, D., Skrøppa, T., & Wolf, H. (2013). Norway spruce (*Picea abies* (L.) H. Karst.). Pâques L. (ed.) *Forest Tree Breeding in Europe. Managing Forest Ecosystems*, (Vol. 25, pp. 123–176). Springer, Dordrecht.
- Katrevičs, J., Neimane, U., Dzerina, B., Kitenberga, M., Jansons, J., & Jansons, A. (2018). Environmental factors affecting formation of lammas shoots in young stands of Norway spruce (*Picea abies* Karst.) in Latvia. *iForest*, 11, 809–815. DOI: 10.3832/ifor2539-011.
- Katrevičs, J., Džeriņa, B., Neimane, U., Desaine, I., Bigača, Z., & Jansons, Ā. (2018). Production and profitability of low density Norway spruce (*Picea abies* (L.) Karst.) plantation at 50 years of age: case study from eastern Latvia. *Agronomy Research*, 16, DOI: 10.15159/AR.18.014.
- Kitenberga, M., Jansons, A., Drobyšev, I., Matisons, R., Niklasson, M., Katrevičs, J., Adamovics, A., & Elferts, D. (2019). A mixture of human and climatic effects shapes the 250-year long fire history of a semi-natural pine dominated landscape of Northern Latvia. *Forest Ecology and Management*, 441, 192–201. DOI: 10.1016/j.foreco.2019.03.020.
- Kitenberga, M., Matisons, R., Jansons, A., & Donis, J. (2018). Teleconnection between the Atlantic sea surface temperature and forest fires in Latvia and Estonia. *Silva Fennica*, 52 (1), 8 p. DOI: 10.14214/sf.7771.
- Lībiete, Z., Matisons, R., Rieksts-Riekstins, J., Priedītis, A., Jansons, J., Smilga, J., Done, G., & Jansons, Ā. (2017). Aboveground biomass equations of 40 year old Norway spruce in Latvia. *Baltic Forestry*, 23(2), 515–521.
- Lībiete-Zālīte, Z., & Jansons, Ā. (2011). Influence of genetic factors on Norway spruce (*Picea abies* (L.) Karst.) above-ground biomass and its distribution. In: Z. Gaile (ed.) *Proceedings of the 17th international scientific conference Research for Rural Development*, 18–20 May 2011 (pp. 39–45). Jelgava, Latvia: LLU.
- Matisons, R., Adamovičs, A., Jansone, D., Bigača, Z., & Jansons, Ā. (2018). Climatic Sensitivity of the Top-Performing Provenances of Scots Pine in Latvia. *Baltic Forestry*, 24(2), 228–233.
- Matisons, R., Puriņa, L., Adamovičs, A., Robalte, L., & Jansons, Ā. (2017). European beech in its northeasternmost stands in Europe: Varying climate-growth relationships among generations and diameter classes. *Dendrochronologia*, Vol. 45, 123–131 pp., DOI: 10.1016/j.dendro.2017.08.004.
- Pretzsch, H., Biber, P., Schütze, G., Uhl, E., & Rötzer, T. (2014). Forest stand growth dynamics in Central Europe have accelerated since 1870. *Nature Communications*, 5. DOI: 10.1038/ncomms5967.
- Runģis, D., Luguza, S., Bāders, E., Šķipars, V., & Jansons, Ā. (2019). Comparison of Genetic Diversity in Naturally Regenerated Norway Spruce Stands and Seed Orchard Progeny Trials. *Forests*, 10, 926; DOI: 10.3390/f10100926.
- Rieksts-Riekstins, J., Jansons, A., Smilga, J., Baumanis, I., Ray, D., & Connolly, T. (2014). Climate suitability effect on tree growth and survival for Scots pine provenances in Latvia. In: Z. Gaile (ed.) *Proceedings of the 20th international scientific conference Research for Rural Development*, 21–23 May 2014 (pp. 57–62). Jelgava, Latvia: LLU.
- Seidl, R., Schelhaas, M.-J., Rammer, W., & Verkerk, P.J. (2014). Increasing forest disturbances in Europe and their impact on carbon storage. *Nature Climate Change*, 4, 806–810. DOI: 10.1038/nclimate2318.
- Schmidt-Vogt, H. (1977). *Die Fichte. Ein Handbuch in zwei Bänden. I Taxonomie, Verbreitung, Morphologie, Ökologie, Waldgesellschaften*. XVIII + 647 S., 304 Abb., 60 Übersichten. Verlag Paul Parey, Hamburg, Berlin. ISBN 3490082168.
- Zeltiņš, P., Katrevičs, J., Gailis, A., Maaten, T., Bāders, E., & Jansons, Ā. (2018a). Effect of Stem Diameter, Genetics, and Wood Properties on Stem Cracking in Norway Spruce. *Forests*, 9, 546; DOI: 10.3390/f9090546.
- Zeltiņš P., Matisons R., Gailis A., Jansons J., Katrevičs J., & Jansons, Ā. (2018b). Genetic parameters of growth traits and stem quality of silver birch in a low-density clonal plantation. *Forests*, 9(2), 52. DOI: 10.3390/f9020052.
- Zeltiņš, P., Katrevičs, J., Gailis, A., Maaten, T., Jansons, J., & Jansons, Ā. (2016). Stem cracks of Norway spruce (*Picea abies* (L.) Karst.) provenances in Western Latvia. *Forestry Studies*, 65, 57–63.

CARBON STOCK IN LITTER AND ORGANIC SOIL IN DRAINED AND NATURALLY WET FOREST LANDS IN LATVIA

*Aldis Butlers^{1,2}, Andis Lazdins²

¹Latvia University of Life Sciences and Technologies, Latvia

²Latvia State Forest Research Institute 'Silava', Latvia

*Corresponding author's email: aldis.butlers@silava.lv

Abstract

The aim of the study is to evaluate carbon stock in litter and organic forest soils in Latvia as well as to characterize accumulation of carbon in litter in afforested lands. The study is providing empirically valid information about soil and litter carbon changes for the National greenhouse gas (GHG) inventory by using data from National forest inventory (NFI), forest soil monitoring demonstration project BioSoil and other studies. The study proves significance of organic forest soil carbon pool in Latvia and demonstrates necessity to extend NFI incorporated forest soil monitoring program to improve data on soil density in wet organic soils, as well as to integrate data characterizing water regime in forests. The acquired data also proves that the conservative approach of calculation of carbon stock changes in litter in afforested lands applied in the Latvia's National GHG inventory avoids overestimation of CO₂ removals. The data on litter carbon stock collected in this study is sufficient to estimate total carbon stock for stands dominated by most common tree species and long term impact of changes of species composition. Measurements of organic soil and litter thickness should be continued by NFI and integrated with more detailed soil monitoring to increase accuracy of carbon stock estimates and gather data necessary for verification of modelling data, particularly in afforested lands and due to change of dominant species.

Key words: carbon stock, litter, organic soil, forest.

Introduction

The net GHG emissions in Latvia in 2017 were 9.6 mill. t CO₂ equivalents (CO₂ eq.) including Land Use, Land Use Change and Forestry (LULUCF) sector and 11.3 mill. t CO₂ eq. without LULUCF sector (Ministry of Environmental Protection and Regional Development, 2019). In 2018 Latvia joined the European Commission initiative 'A clean planet for all. A European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy' (European Commission, 2018) by setting the GHG neutrality target in 2050. According to this proposal, the GHG emissions in Latvia have to be reduced by nearly 10 mill. t CO₂ eq. during the following 30 years. The LULUCF sector will have an important role in reaching this target because of considerable potential to decrease GHG emissions within the sector by implementation of the GHG mitigation measures in forest land, cropland, grassland and wetlands. In addition, LULUCF sector can contribute to the national target by providing replacement of fossil resources utilized in energy sector and other industries. Scientifically verified data on current status of carbon stock and the potential impact of mitigation measures are of particular importance to avoid misleading actions, as well as to avoid underestimation or overestimation of the projected GHG emissions (Rogelj *et al.*, 2015).

According to the IPCC guidelines (Eggleston *et al.*, 2006), litter is considered as emission neutral carbon pool creating CO₂ emissions or removals in case of land use changes, as well as peat in naturally wet organic soils in forest lands. C-stock in organic

soils have been evaluated in several previous studies (Lazdiņš, Butlers, & Lupiķis, 2014; Lazdiņš, Lupiķis, & Okmanis, 2014; Lazdiņš & Lupiķis, 2014; Lazdiņš, 2015). Carbon stock in litter layer in forest land in Latvia is 12.14 t C ha⁻¹ according to BioSoil results (Bārdule *et al.*, 2009). However, results of previous studies does not provide comprehensive whole country representative data on C-stock in litter and organic soils in forests stratified by soil moisture regime, stand age and dominant tree species.

NFI is the main source of activity data for National GHG inventory. NFI data is used to continuously improve the growth models (Lazdiņš *et al.*, 2019) used to evaluate the impact of mitigation measures, e.g. afforestation or change of the dominant tree species (Bērziņa *et al.*, 2018; Lazdiņa *et al.*, 2019) on carbon stock in soil and litter. In order to acquire information necessary to characterize C-stock in litter and organic soil depending from stand properties, measurements of litter and peat layer depth were incorporated in NFI surveys in 2017.

The aim of the study is to evaluate carbon stock in litter and organic soils in drained and naturally wet forest as well as to characterize accumulation of carbon in litter in afforested lands, by aggregation of latest data on C stock from NFI surveys and previous studies.

Materials and Methods

Measurement of depth of organic soil and litter layer is done in NFI plots categorized as forest lands considering every plot as a single unit. NFI uses a permanently below ground marked 4 × 4 km grid

Table 1

Carbon content and soil density data applied in calculation

Layer	Average data		Uncertainty range	
	density, kg m ⁻³	carbon content, g kg ⁻¹	density, kg m ⁻³	carbon content, g kg ⁻¹
Litter	76.6	540.6	15.9	5.0
0–10 cm	190.3	497.4	29.3	16.2
10–20 cm	206.1	489.1	34.3	23.5
20–40 cm	256.7	478.5	53.9	29.3
40–70 cm	319.5	447.2	71.4	35.3

across all of the country with four permanent sample plots of 500 m² size at each grid point. In total, 16,157 sample plots are used for calculations of land use and carbon stock changes. Each sample plot is surveyed once during a complete cycle of the monitoring of forest resources, i.e., once every 5 years. Borders of sample plots are constant during all NFI cycles, each plot on average represents about 400 ha of the country area including inland water bodies.

Depth of organic layer is measured with soil auger in 4 places (north, east, south and west direction) 2...3 m from outer border of the plot. Total thickness of organic soil layer and litter is determined separately. Intercalibration training session is organized every spring before measurements to harmonize results. In case of unclear transition between mineral and organic layer, middle of transition layer is considered as depth of organic layer. Depth of organic soil is measured down to 70 cm depth, therefore in results instead of the total peat depth relative depth is expressed, respectively, 100% corresponds to 70 cm and 0% corresponds to 0 cm. Data from 6,870 NFI plots surveyed in 2017...2019 are used for purpose of this study. The monitoring will be continued for at least 2 more years to survey all NFI plots in forest lands.

Recalculation from soil and litter layer to carbon stock is done using BioSoil demonstration project data (95 plots in total) on soil density and carbon content. Soil characteristics from 11 plots were selected as

suitable and used in calculation. Additional soil bulk density data from other studies with organic soils were applied (Lazdiņš, Butlers, & Lupiķis, 2014; Lazdiņš, Lupiķis, & Okmanis, 2014; Lazdiņš & Lupiķis, 2014; Lazdiņš, 2015). Only 3 plots are located in wet organic soils, therefore average data (soil density and carbon stock) from organic soils are used in calculation. This may lead to overestimation of carbon stock in wet soils represented by limited number of plots. Summary of applied data are provided in Table 1.

Uncertainty is calculated as standard error of mean, uncertainty of area and average carbon stock per NFI plot is used to estimate uncertainties of the total and average values.

Results and Discussion

The evaluation of carbon stock in litter is split in 2 parts – carbon stock in afforested land and carbon stock in forest land remaining forest (forest land for at least 2 rotations). Summary of the calculation of carbon stock in litter in afforested land is provided in Table 2. For the most of the species considerable uncertainty is found in the data; however, there is a tendency of increase of average carbon stock in litter with increasing age of the stand. This trend is characterized by logarithmic regression (Figure 1). Average area weighed carbon stock in afforested lands up to 50 years age is 2.33±0.05 t ha⁻¹, and average carbon stock in 20 years old forests in afforested lands

Table 2

Carbon stock in litter in afforested land representing different age decades and dominant tree species (t C ha⁻¹)

Species	Age decade					Average stock
	1	2	3	4	5	
Aspen (<i>Populus tremula</i> L.)	4.36±0.65	1.9±0.15	4.61±2.2	3.83±8.24	–	1.9±0.04
Birch (<i>Betula pendula</i> Roth)	1.87±0.2	2.18±0.01	3.17±0.06	5.08±5.13	3.14±2.79	3.6±0.01
Grey alder (<i>Alnus incana</i> (L.) Moench)	0.5±0.04	1.22±0.03	4.81±0.33	2.76±0.54	3.12±6.82	1.83±0.01
Spruce (<i>Picea abies</i> (L.) H. Karst.)	–	1.3±0.09	2.25±0.19	5.75±0.05	–	1.06±0.02
Pine (<i>Pinus sylvestris</i> L.)	0.19±0.22	3.2±0.18	0.44±0.31	2.87±0	4.66±10.02	2.27±0.19

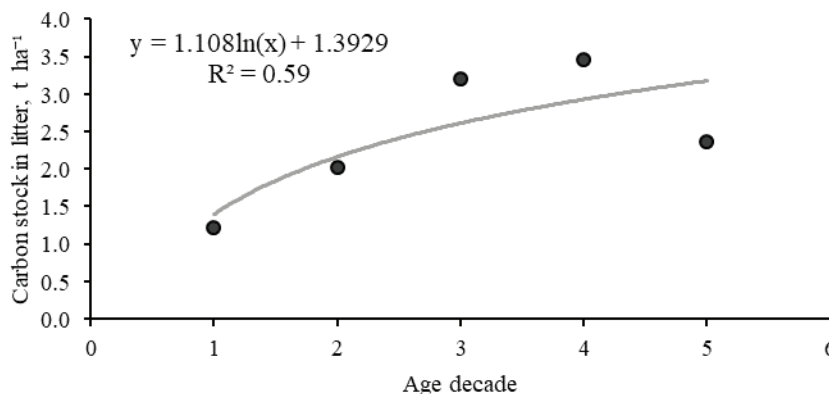


Figure 1. Stand age and average carbon stock in litter in afforested lands.

is $2.02 \pm 0.02 \text{ t ha}^{-1}$. This means that application of the default approach by the Intergovernmental Panel on Climate Changes (IPCC) 2006 guidelines (Eggleston *et al.*, 2006), respectively, use of 20 years transition period for this carbon pool would lead to significant overestimation of CO_2 removals in afforested lands. Latvia is currently using much more conservative approach – 150 years transition period for the litter, as well as dead wood carbon pools, assuming that 2 rotations of trees are necessary to reach the average values of carbon stock (Ministry of the Environment, 2019). The study approves that this approach, in spite of being very conservative, increases accuracy of carbon stock changes in litter estimations.

The regression provided in Figure 1 can be used for projections of short term (4...5 decades) carbon

stock changes in the litter pool in afforested lands. For projection of long term changes, it should be extended with data from mature and second rotation forests, where the rate of carbon accumulation in litter may increase. The Number of black alder (*Alnus glutinosa* (L.) Gaertn.), ash (*Fraxinus excelsior* L.) and oak (*Quercus robur* L.) dominant NFI plots is insufficient to estimate carbon stock in litter in afforested lands.

In the forest land, remaining forest average carbon stock in litter is 5 times larger in comparison to afforested lands – $11.07 \pm 0.05 \text{ t ha}^{-1}$. Strong correlation is found between carbon stock in litter and age of forests, particularly, in coniferous forests and when average values of all species are compared ($R^2 = 0.85$); however, in grey alder, ash and oak stands this correlation is even negative. Summary of

Table 3

Carbon stock in litter in forest land remaining forest representing different age decades and dominant tree species (t C ha^{-1})

Age decade	Aspen	Birch	Grey alder	Spruce	Black alder	Ash, oak	Pine	Other species
1	7.32±0.02	10.93±0.01	3.34±0.01	8.79±0.03	10.85±0.1	6.99±0.56	17.41±0.06	1.85±0.51
2	3.43±0.02	6.88±0.01	3.38±0.01	8.77±0.02	6.5±0.06	5.19±0.36	14.22±0.04	3.72±0.2
3	3.04±0.06	6.42±0.01	3.75±0.02	11.52±0.03	7.41±0.28	–	16.48±0.08	2.28±0.14
4	7.38±0.36	7.3±0.02	4.57±0.02	11.01±0.02	6.09±0.07	1.94±0.61	17.53±0.12	6.48±0.46
5	8.94±0.12	9.16±0.01	4.05±0.01	15.41±0.02	8.38±0.09	2.67±0.64	16.33±0.07	2.3±0.25
6	6.84±0.05	7.47±0.01	0.92±0.03	14.71±0.03	7.92±0.04	5.91±3.73	19.13±0.03	–
7	6.25±0.04	6.87±0.01	2.98±0.21	11.93±0.04	10.58±0.1	2.78±0.68	18.91±0.02	2.77±0.41
8	8.00±0.13	8.39±0.02	3.55±2.04	15.84±0.06	8.34±0.13	1.28±0.52	20.46±0.02	–
9	4.34±0.57	7.18±0.05	–	16.27±0.12	5±0.78	10.89±3.33	20.13±0.02	–
10	12.45±4.99	5.98±0.18	–	16.21±0.18	8.75±1.45	5.81±1.98	18.38±0.02	5.75±7.47
11	32.09±50.49	14.32±5.08	–	10.89±0.35	–	5.01±2.68	20.2±0.04	–
12	–	19.98±35.27	–	16.27±0.72	–	–	16.23±0.05	–
13	57.48±0	–	–	24.84±4.43	–	–	16.04±0.1	–
14	–	–	–	10.74±5.27	–	–	15.78±0.22	–
15	–	–	–	13.09±3.57	–	–	14.1±0.22	–

the calculation of carbon stock in litter in forest land remaining forest is provided in Table 3. The largest values of carbon stock are found in coniferous forests and mature aspen stands. It is important to note that mature aspen stands are usually coniferous forests with several large aspens forming the largest growing stock in a particular NFI plot. Therefore, large carbon stock in litter in aspen stands also relates to coniferous species.

The study results approve an earlier finding that accumulation of litter and immobilization of nutrients, particularly nitrogen, takes place in mature coniferous forests resulting in shortage of the nutrients and decreased growth rate (Forest Fertilization., 1968; Binkley & Fisher, 2012).

The carbon stock dynamics in the litter pool depending on the forest age is characterized by polynomial regression (Figure 2), which demonstrates reduction of carbon stock in young stands and increase of carbon in mature forests with following decrease of carbon stock in decaying forests. It is important to note that 100 years old and older stands are mostly represented by coniferous species.

The largest carbon stock in litter is in coniferous stands; significantly smaller it is in deciduous species

(Figure 3). The difference is statistically significant. Similar regularity is found also in afforested lands (Table 2).

The correlation between growing stock and carbon stock in litter is also studied; however, no correlation was found. Statistical analysis shows that the study results can be used to estimate long term impact of species composition on carbon stock in litter, but more data are necessary to estimate the impact of age structure at a species level.

Other task of the study is evaluation of peat depth in order to calculate carbon stock in drained and wet forests organic soils. Nutrient-poor and nutrient-rich organic soils, wet and drained soils, and different dominant species are evaluated separately (Table 4). No significant differences were found depending on growth conditions and dominant species, except pine stands, which are growing on deeper peat soils in nutrient poor conditions. The thinnest peat layer is in aspen and grey alder stands (Figure 4).

In 50% of sample plots in forests with organic soils surveyed in 2017–2019, peat layer is less than 50 cm in drained forests, and less than 60 cm in forests with wet soils. In 18% of forests with organic soil, according to national definition, it was found that peat

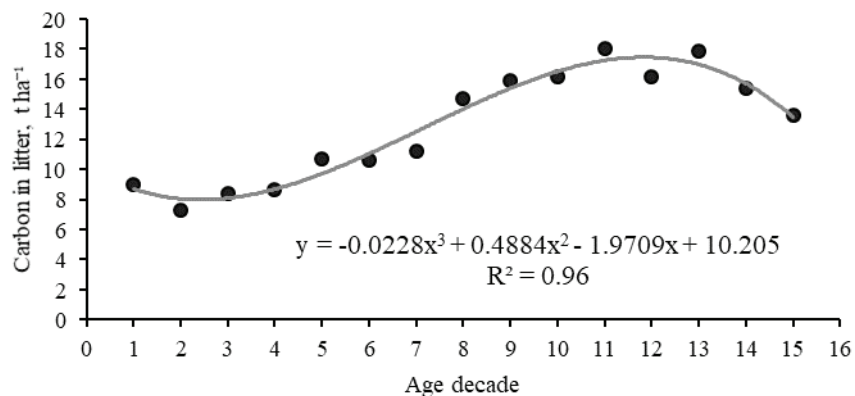


Figure 2. Stand age and average carbon stock in litter in forest land remaining forest.

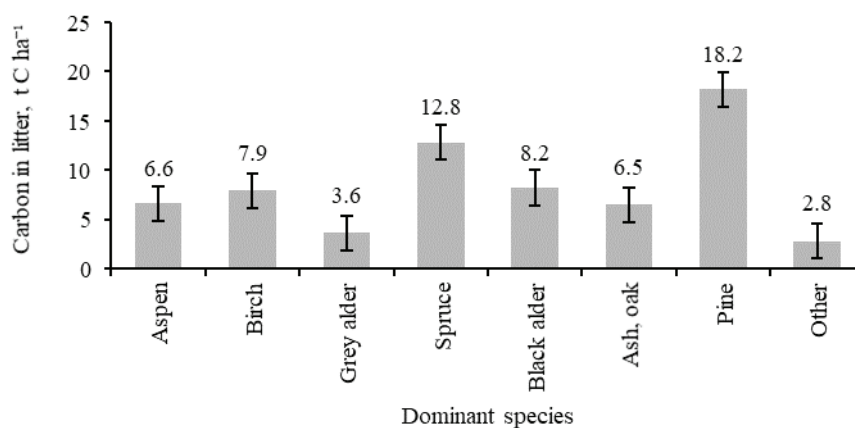


Figure 3. Stand age and average carbon stock in litter in forest land remaining forest.

Table 4

Relative peat depth in forests with wet and drained peat soils, %

Growth conditions		Aspen	Birch	Grey alder	Spruce	Black alder	Pine	Average
Drained soils	nutrient-poor	50	84	21	37	–	75	76
	nutrient-rich	13	60	27	55	43	33	52
Wet soils	nutrient-poor	31	64	–	56	65	76	73
	nutrient-rich	18	60	24	65	35	–	37

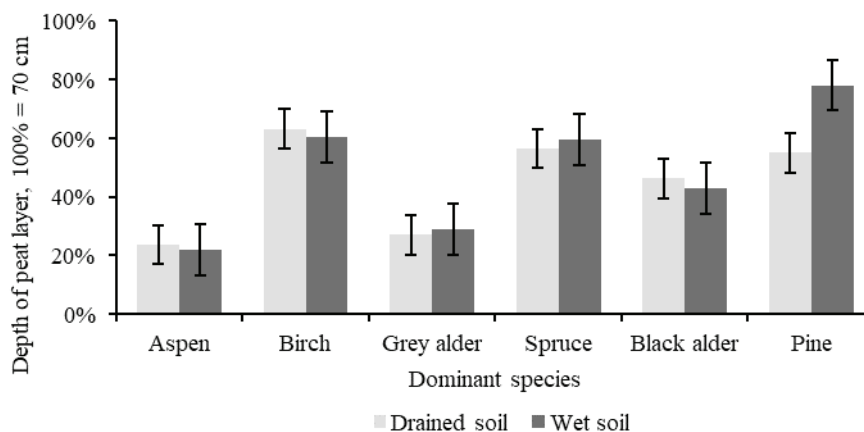


Figure 4. Comparison of peat depth in forest with drained and wet organic soils with different dominant species.

depth is below 20 cm, respectively these soils might not be considered as organic soils according to IPCC definition (Hiraishi *et al.*, 2013). In forests with wet soils in 23% cases peat layer is less than 30 cm. At the same time in 25% of forests with drained soil and in 33% of forests with wet organic soil peat depth is more than 70 cm.

Calculation of carbon stock in soil includes 70 cm deep layer, excluding potential carbon stock in mineral soil layers underlying peat layer and includes litter layer. Carbon stock in litter in forest stand types with organic soils according to national definition in Latvia is 7.7 mill. t C, including 3.2 mill. t C in forests with wet soils and 4.5 mill. t C forests with drained soils. Carbon stock in soil in forest stand types with organic soils according to national definition is 234 mill. t C, including 120 mill. t C in forests with drained soils and 114 mill. t C in forests with wet soils. Total carbon stock in forests with organic soils according to national definition is 242 mill. t C (Table 5).

It is necessary to extend forest soil monitoring program by inclusion more sample plots representing dry and wet organic soils, which contribute to the most of GHG emissions in LULUCF sector in Latvia (Lazdiņš, 2020; Ministry of the Environment, 2019). In parallel, it is necessary to improve activity data on moisture regime in forests with organic soils, because it is found in several studies, e.g. by Lazdiņš (2020)

that groundwater depth does not differ significantly in drained and wet soils at the end of vegetation period.

Summarized data on soil and litter carbon stock in forest stand types with organic soils according to national definitions is shown in Figure 5. Considering relatively small number of plots these values may have significant uncertainty. The largest carbon stock is in pine stands, it is relatively smaller in aspen and grey alder stands due to thin peat layer. Carbon stock in wet soils may be overestimated due to limited data available on the density of organic soil layers in wet forest soils.

Estimated carbon stock in litter and soil in forests with organic soils is by 16% larger than carbon stock in mineral soils at 0...30 cm depth (Bārdule *et al.*, 2009; Lazdiņš *et al.*, 2013) and is nearly equal to carbon stock in living biomass in forest lands (Ministry of the Environment, 2019). Total carbon stock in forest lands according to the study results is 762 mill. t, including 31% in organic soils.

The results prove significance of further studies on carbon stock changes in forest soils and accurate evaluation of soils' properties in forest inventories, because organic soils (according to IPCC definition) were found in all growth conditions. This means also that principle of calculation of GHG emissions in forests should be changed from growth conditions based equations to soil characteristics based models to improve accuracy.

Table 5

**Carbon stock in organic soil and litter in different growth
Conditions and dominant species stands (1000 t C)**

Growth conditions		Aspen	Birch	Grey alder	Spruce	Black alder	Pine	Other species	Total
Litter									
Drained soil	nutrient-poor	2.6	107.3	8.9	80.0	–	682.7	10.4	892.0
	nutrient-rich	97.4	1236.1	35.7	734.3	280.7	1082.9	118.9	3586.0
	total	100.0	1343.4	44.6	814.3	280.7	1765.6	129.3	4478.0
Wet soil	nutrient-poor	14.0	516.9	0.0	179.6	86.4	1326.9	19.1	2142.9
	nutrient-rich	8.1	377.6	89.0	85.7	478.2	–	43.4	1081.9
	total	22.2	894.5	89.0	265.2	564.6	1326.9	62.5	3224.8
Sum total		122.1	2237.9	133.6	1079.5	845.3	3092.5	191.8	7702.8
Peat at 0–70 cm depth									
Drained soil	nutrient-poor	347.3	8352.9	79.9	2533.7	–	18483.4	535.3	30332.6
	nutrient-rich	952.8	40768.5	1819.4	18452.5	10018.3	15022.2	2425.8	89459.4
	total	1300.1	49121.4	1899.3	20986.2	10018.3	33505.6	2961.2	119792.0
Wet soil	nutrient-poor	240.6	16554.3	0.0	3179.9	2203.2	56188.8	1128.4	79495.2
	nutrient-rich	267.7	17813.4	1393.8	3307.2	11566.6	–	412.7	34761.3
	total	508.3	34367.7	1393.8	6487.1	13769.8	56188.8	1541.0	114256.5
Sum total		1808.4	83489.1	3293.1	27473.3	23788.1	89694.4	4502.2	234048.5
Total litter and soil		1930.5	85727.0	3426.7	28552.8	24633.4	92786.9	4694.0	241751.3

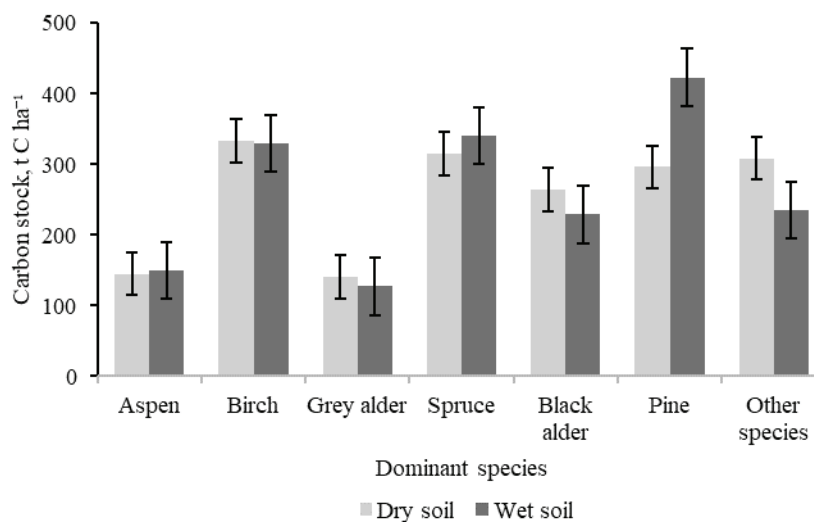


Figure 5. Average soil and litter carbon stock in drained and wet soils in forest stand types with organic soils according to national definition.

Conclusions

1. The results of the study proves significance of soil carbon pool in organic forest soils in Latvia (31% of the total carbon stock in forest lands), as well as demonstrate necessity to improve soil density data on wet organic soils, which can have significant impact on GHG emissions in forest lands.
2. The study proves that the conservative approach of calculation of carbon stock changes in litter

applied in the Latvia's National GHG inventory avoids overestimation of CO₂ removals due to afforestation. Further studies in mature forests and second generation of trees on afforested lands are necessary to improve the soil carbon flux modelling capabilities.

3. Obtained data is sufficient to estimate total carbon stock and long term impact of changes of species composition on litter layer, e.g. growing

of deciduous trees instead of coniferous trees; however, potential overestimation of presented carbon stock in wet organic soil calculation should be considered.

4. The study demonstrates that the stand type based estimation of soil carbon stock changes may lead to biased estimates due to considerable share of organic soils present in stands classified as with mineral soil.

Acknowledgements

The measurement data are acquired within the scope of the memorandum between LSFRI Silava and Joint stock company 'Latvia state forests' from 11.10.2011; the data analysis is implemented within the scope of ERAGAS program INVENT project.

References

- Forest Fertilization: Theory and Practice* (1968). Knoxville: Tennessee Valley Authority National Fertilizer Development Center.
- Bārdule, A., Bāders, E., Stola, J., & Lazdiņš, A. (2009). Latvijas meža augsņu īpašību raksturojums demonstrācijas projekta BioSoil rezultātu skatījumā (Forest soil characteristic in Latvia according to results of the demonstration project BioSoil). *Mežzinātne*. 20 (53), 105–124. (in Latvian).
- Bērziņa, L., Degola, L., Grīnberga, L., Kreišmane, D., Lagzdiņš, A., Lazdiņš, A., Lēnerts, A., Lupiķis, A., Naglis-Liepa, K., Popluga, D., Rivža, P., & Sudārs, R. (2018). *Siltumnīcefekta gāzu emisiju samazināšanas iespējas ar klimatam draudzīgu lauksaimniecību un mežsaimniecību Latvijā (Possibilities for reducing greenhouse gas emissions with climate-friendly agriculture and forestry in Latvia: a monograph)*. Jelgava: Latvijas Lauksaimniecības universitāte. (in Latvian).
- Binkley, D., & Fisher, R. (2012). *Ecology and Management of Forest Soils*. New York: Wiley-Blackwell.
- European Commission (2018). *COM(2018) 773 final Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee, the Committee of the Regions and the European Investment Bank A clean planet for all a European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy*. Brussels: European Commission.
- Eggleston, S., Buendia, L., Miwa, K., Ngara, T., & Kiyoto, T. (2006). *2006 IPCC Guidelines for National Greenhouse Gas Inventories. Agriculture, Forestry and Other Land Use*. Japan: Institute for Global Environmental Strategies (IGES).
- Hiraishi, T., Krug, T., Tanabe, K., Srivastava, N., Fukuda, M., Troxler, T., & Jamsranjav, B. (2013). *2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands*. Japan: Intergovernmental Panel on Climate Change.
- Lazdiņa, D., Lazdiņš, A., Bebre, I., Lupiķis, A., Makovskis, K., Spalva, G., Sarkanābols, T., Okmanis, M., Krīgere, I., Dreimanis, I., & Kalniņa, L. (2019). *Sustainable and responsible after-use of peat extraction areas*. Rīga: Baltijas krasti.
- Lazdiņš, A. (2020). Kūdras augsnes Latvijas siltumnīcefekta gāzu bilancē – klimata izmaiņu mazināšanas izaicinājumi un iespējas (Peat soils in Latvia's greenhouse gas balance – climate change mitigation challenges and opportunities). In Latvijas Universitātes 78. zinātniskā konference 'Bioloģija', 7 February 2020. Rīga: Latvijas Universitāte. (in Latvian).
- Lazdiņš, A., Bārdule, A., Stola, J., & Krišāns, O. (2013). Temporary carbon stock changes in forest soil in Latvia. In International Baltic Sea Regional Scientific Conference: Interdisciplinary Research for Higher Socioeconomic Value of Forests, 10–12 June 2013 (pp. 51–52). Salaspils: Latvian State Forest Research Institute 'Silava'.
- Lazdiņš, A., Butlers, A., & Lupiķis, A. (2014). Case study of soil carbon stock changes in drained and afforested transitional bog. In 9th Baltic theriological conference: Forest Ecosystems and Its Management: Towards Understanding the Complexity I, 15 October 2014 (pp. 39–40). Daugavpils: Daugavpils University.
- Lazdiņš, A., & Lupiķis, A. (2014). *Hidrotehniskās meliorācijas ietekme uz CO₂ emisijām mežaudzēs uz susinātām augsnēm (Impact of hydrotechnical melioration on CO₂ emissions from forests on drained soils)*. Salaspils: Latvijas Valsts mežzinātnes institūts 'Silava'. (in Latvian).
- Lazdiņš, A., Lupiķis, A., & Okmanis, M. (2014). Soil carbon stock change due to drainage of a forest stand growing on a transitional bog. In Extended abstracts of the CAR-ES network meeting in Finland, 20–22 October 2014 (pp. 50–53). Vantaa, Finland: Finnish Forest Research Institute.
- Lazdiņš, A., Šņepsts, G., Petaja, G., & Kārklīņa, I. (2019). Verification of applicability of forest growth model AGM in elaboration of forestry projections for National forest reference level. In Proceedings of the 9th International Scientific Conference 'Rural Development 2019', 26–28 September 2019 (pp. 289–294). Lithuania: Vytautas Magnus University Agriculture Academy.

- Lazdiņš, A. (2015). *Augsnes CO₂ emisiju koeficientu izstrādāšana auglīgām organiskām augsnēm – šaurlapju un platlapju kūdreņiem (Development of CO₂ Emission Factors for Soil in Fertile Organic Soils in Myrtillosa turf. mel. and Oxalidosa turf. mel. forest types)*. Salaspils: Latvijas Valsts mežzinātnes institūts ‘Silava’. (in Latvian).
- Ministry of Environmental Protection and Regional Development (2019). *Latvia’s National Inventory Report Submission under UNFCCC and the Kyoto protocol Common Reporting Formats (CRF) 1990 – 2017*. Latvia: Ministry of Environmental Protection and Regional Development of the Republic of Latvia.
- Ministry of the Environment. (2019). *Greenhouse gas emissions in Estonia 1990–2017. National inventory report. Submission to the UNFCCC Secretariat. Common Reporting Formats (CRF) 1990–2017*. Estonia: Ministry of the Environment.
- Rogelj, J., Schaeffer, M., Meinshausen, M., Knutti, R., Alcamo, J., Riahi, K., & Hare, W. (2015). Zero emission targets as long-term global goals for climate protection. *Environmental Research Letters*. 10(10). DOI: 10.1088/1748-9326/10/10/105007.

COMPARISON OF REGENERATION OF SCOTS PINE *PINUS SYLVESTRIS* L. IN *MYRTILLOSA* AND *HYLOCOMIOSA* FOREST TYPES AFTER SHELTERWOOD CUTTINGS

Oto Rums¹, *Inga Straupe¹, Leonīds Zdors²

¹Latvia University of Life Sciences and Technologies, Latvia

²Latvian State Forest Research Institute 'Silava', Latvia

*Corresponding author's email: inga.straupe@llu.lv

Abstract

The aim of the study is to determine how successful the initial growth of naturally grown and planted pines is after performing the shelterwood cutting. The research includes tree count and height analysis in *Myrttilosa* and *Hylocomiosa* forest types with different regeneration methods in 2018. A total of 10 sites were arranged for the research, each site having 4 sample plots. All naturally regenerated and planted pine (2009, 2012 and 2013) heights were measured. Judging by the number of trees after shelterwood cutting, most sites should not be considered regenerated, additional planting or scarification of soil is required which can improve the efficiency of natural regeneration. In all the sites both in *Myrttilosa* and *Hylocomiosa*, after shelterwood cutting it was observed that the height of artificially regenerated trees is higher than the height of naturally regenerated trees, indicating the ability of planted pines to produce more rapid height increment in the first years of life, regardless of forest type. The basal area of the stand has a significant negative impact on the increment, and it indicates the need for the subsequent shelterwood cut to be performed. Although *Hylocomiosa* is a more fertile forest type than *Myrttilosa*, the height of the planted pine trees in *Myrttilosa* is higher than in *Hylocomiosa*, where, after shelterwood cutting, no sufficiently intensive agro-technical tending has been performed.

Key words: *Pinus sylvestris*, natural regeneration, artificial regeneration, *Myrttilosa*, *Hylocomiosa*.

Introduction

Shelterwood cutting is a type of final felling where a mature stand is felled in several turns. The advantages of this method include landscape attractiveness and continuous tree canopy closure, reduced impact of biotic and abiotic disturbances as well as reduced competition of herbaceous plants. The forest stand is expected to regenerate in a natural way in the shelterwood cutting sites. In some cases, trees are also planted. In order for natural regeneration to fully occur in shelterwood cuttings, at the beginning of their life young trees need to be shielded by old trees, and this shield can serve as a seed base and protect them from frost and other hazards (Matthews, 1991). The retained trees also preserve the ecological legacies and help maintain the existing vegetation composition of the forest stand (Nyland, 2016). With this type of felling, the soil is better protected from drying out, which is facilitated by open felling areas (Matthews, 1991). A successful shelterwood cutting site regeneration involves the practice of naturally regenerated trees being supplemented with planted ones, thus ensuring an even and complete regeneration with the desirable tree species (Matthews, 1991). By cutting down a part of mature trees in shelterwood sites, the remaining trees are provided with favorable growth conditions, thus making it possible to obtain high-quality and large-dimension commercial wood in the forest. The old generation of Scots pine needs to be preserved until the new generation is fully developed, and when this has happened, it is advisable to cut down the mature trees or significantly reduce their number in the forest stand (Valkonen, 2014). In the research

on group shelterwood cuttings in Latvia, the positive increment in the trunk volume is attained two years after felling, whereas the positive effect of the openings is observed in a 7 m zone around them. Accordingly, the volume increments in the trees which are farther than 7 m away from the openings are several times smaller (Zdors *et al.*, 2017). The average tree height increment in shelterwood cuttings at the distance of 10 m from the stand's mature trees is similar to the height increment of planted Scots pine trees in clearcut areas (Strand *et al.*, 2006). The incremental growth of the trees remaining in continuous shelterwood sites depends on the basal area of the thinned stand, where larger increments are expected at a smaller basal area of the stand (Donis, 2015).

Studies have shown that the light requirements of young plants increase with age. Under shady growing conditions, the diameter of Scots pine is expected to decrease, which means that the pines of the same height will be thinner in shaded areas, whereas larger diameter trees will be able to grow in areas where more light is available (Gaudio *et al.*, 2011). Consequently, as light conditions increase, the diameter of the pine root collar also increases, indicating a better root system development (Zdors & Donis, 2017).

In the planted areas of shelterwood cuttings, the height increments of the Scots pine trees planted after the first cut decreased compared with the growth demonstrated three years after the cut. This is explained by the increasing demands for resources facilitating growth, such as – nutrients, water and light as seedlings develop. In practice, the adverse effects of competition of tree stand can be avoided by timely

planned next shelterwood cut technique or by even more extensive thinning of mature trees in the forest stand (Nilsson *et al.*, 2006). Thinning of the tree stand in advance in shelterwood cutting promotes the growth of herbaceous vegetation due to the available amount of light, which makes it difficult for pine seeds to reach the soil. As light intensity increases, soil temperature also rises, which increases the trees' competition for water resources in the summer months (Barbeito *et al.*, 2011). Competition between planted Scots pine is observed after 4–6 years. As they reach this age, the tree crowns gradually form the canopy closure and the roots of the trees also begin to compete with each other, which determines the future development of the tree stand (Jansons, 2008).

The aim of the study is to determine how successful the initial growth of naturally grown and planted pines is after performing the shelterwood cutting.

Materials and Methods

A total of 10 sites were arranged for the research, each site having 4 sample plots. The forest types were *Myrtillosa* and *Hylocomiosa*. Four sites are located in the western part of Latvia, on the southwestern coast of the Gulf of Riga in the lowland plain, while six sites are located in the eastern part of Latvia, in the North Vidzeme. In each site four 500 m² circular plots were arranged (Figure 1). The distance between the centres of the plots was at least 30 m, and the centres were placed at least 30 m from the edge of the stand. In the sample plot (radius 12.62 m; area 500 m²) all naturally regenerated and planted pine (2009, 2012 and 2013) with a diameter at breast height of more than 14.0 cm were measured. Trees with a diameter of more than 6.0 cm but not exceeding 14.0 cm were measured within a radius of 5.64 m from the sample plot centre

(in the area of 100 m²). Trees with a diameter of 2.1 – 6.0 cm were measured within a radius of 3.99 m from the centre of the sample plot (area 50 m²) (Figure 2). For each tree, its distance from the centre, its species, layer, current status (growing, snag or log) and diameter were recorded. The logs were measured at a distance of 1.3 m from the root collar. In each sample plot at least three tree heights were measured, so that the total number of trees measured would be at least 12 trees per site. For the assessment of plantings and natural regeneration, circular plots of 25 m² were established in the sample plots. The centres of these plots were located in the centres of the large circular sample plots and at a distance of 6 m from them in the N and S directions. All naturally regenerated and planted pine heights were measured. Four of the shelterwood sites were cut in 2013, two in 2012, and four other sites were cut in 2009. When analysing the tree heights, no significant differences were found in the tree heights between the sites felled in 2012 and 2013; therefore, both data sets were analysed together. In the sites, the parameters of the stand were calculated for each sample plot – average diameter, average height, basal area, tree volume, standing volume, average root collar diameter of young trees, and average annual increments, using generally accepted formula in forest inventory parameters (Skudra & Dreimanis, 1993; Liepa, 1996; Sharma & Breidenbach, 2015). In the regeneration assessment, the height analysis of the new generation of trees was performed using the data processing programme SPSS, applying the tool Univariate Analysis of Variance.

Results and Discussion

The researched forest stands have been regenerated in different ways: five of them naturally and five

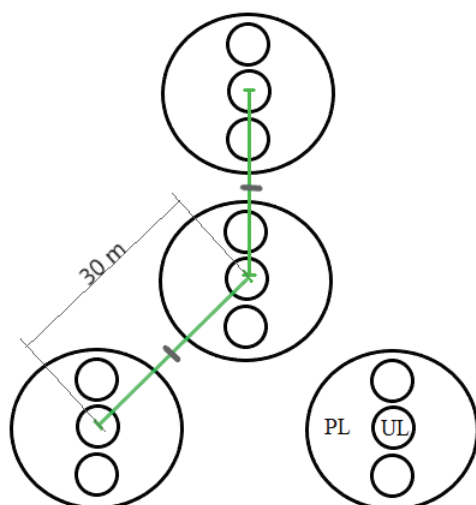


Figure 1. The distribution of sample plots in the object. Abbreviations: PL – sample plot, UL – plot.

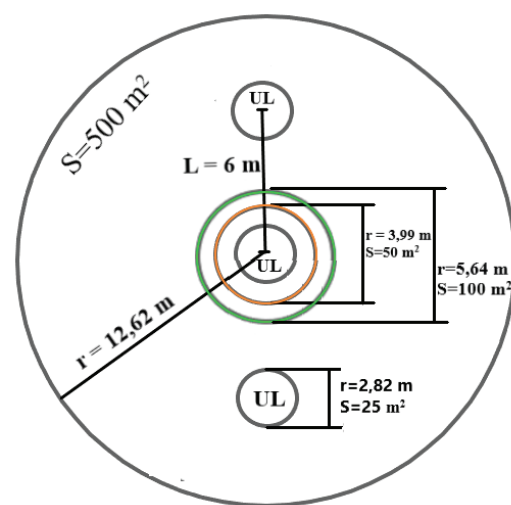


Figure 2. The size of sample plots and plots. Abbreviations: UL – plots, S – area, r – radius, L – distance.

Table 1

The number of trees in objects, where Scots pine was planted

Number of object, forest type, year of felling	P_{pl} , N*ha ⁻¹	P_{nat} , N*ha ⁻¹	$P_{nat} + P_{pl}$, N*ha ⁻¹	Uniformity of regeneration (success of regeneration), %
1 H, 2013	1266.7±230.1	3633.3±861.9	4900±1008	83.3
2 H, 2013	933.3±242.9	4400±926.4	5333.3±1044.9	58.3
3 M, 2013	1133.3±189.6	13866.7±2099	15000±2135.1	100
4 M, 2009	1000±159.5	2300±587	3300±611.3	41.6
5 M, 2009	1000±187.5	1233.3±301.3	2233.3±436.1	41.6

Abbreviations: P_{pl} – planted trees; P_{nat} – naturally regenerated trees; N – number; H – *Hylocomiosa*; M – *Myrtillosa*.

Table 2

The number of trees in objects where natural regeneration was carried out

The number of object, forest type, year of felling	P_{nat} , N*ha ⁻¹	Uniformity of regeneration (success of regeneration), %
6 H, 2013	5600±1231.9	66.67
7 M, 2012	7166.7±1378.1	75
8 H, 2012	3566.7±945.1	33.3
9 M, 2009	3700±694.8	50
10 M, 2009	5666.7±671.2	100

Abbreviations: P_{nat} – naturally regenerated trees; N – number; H – *Hylocomiosa*; M – *Myrtillosa*.

artificially. In all stands the dominant tree species is Scots pine, five stands are composed only of Scots pine trees. The rest of the sites have the admixture of other tree species. The number of old-generation trees in the studied sites ranges from 65 to 235 trees per hectare, the average tree height in the sites is from 24.6 m to 34 m and the average DBH - from 32.4 cm to 59.6 cm.

Analysis of the number of trees in the research sites. According to Latvian legislation, the minimum required number of the established trees which are to be regenerated with Scots pines is 3000 trees per hectare. The number of trees in the researched shelterwood sites where planting was carried out is shown in Table 1.

The number of trees according to their origin (natural or artificial) is calculated as an average parameter in all 12 plots in the site. The number of planted pines in all the research sites is not sufficient to consider the area as regenerated. Pine regeneration naturally has been much more successful, reaching up to 13 866 trees per hectare in one site. By combining the number of planted and naturally regenerated pines, the average number of young trees in four of the five sites is sufficient, and the minimum required number of the plants that have established in these sites has been exceeded.

An important indicator for the evaluation of stand regeneration is the uniformity of regeneration (%)

which characterizes the success of the regeneration in the site as a whole. It is calculated by determining the ratio between the number of accounting areas in the site where the total amount of artificially and naturally regenerated trees reaches at least the minimum number of trees required, which is 3000 trees per hectare, and the total number of accounting areas which equals 12. When calculating the uniformity of the regeneration, it can be concluded that only two of the five planted sites have achieved the necessary criteria for a stand to be considered regenerated – regeneration has been uniformed over the area of 83.3% and 100% respectively. The sites where natural regeneration was planned after shelterwood cutting are shown in Table 2.

The average number of trees in all sites was more than the minimum number of trees required per hectare, but also in these sites the regeneration was not uniformed throughout the stand, with the highest average number of trees by the accounting areas being 7166.7 ± 1378.1 trees and the lowest average amount in the site 3566.7 ± 945.1 trees per hectare. Only one site is considered to be uniformly regenerated. Analysing the number of trees in sites, it can be concluded that, irrespective of the type of regeneration, most sites after shelterwood cutting are not to be considered regenerated. It is anticipated that when subsequent cuts are carried out, additional space for natural regeneration will be provided.

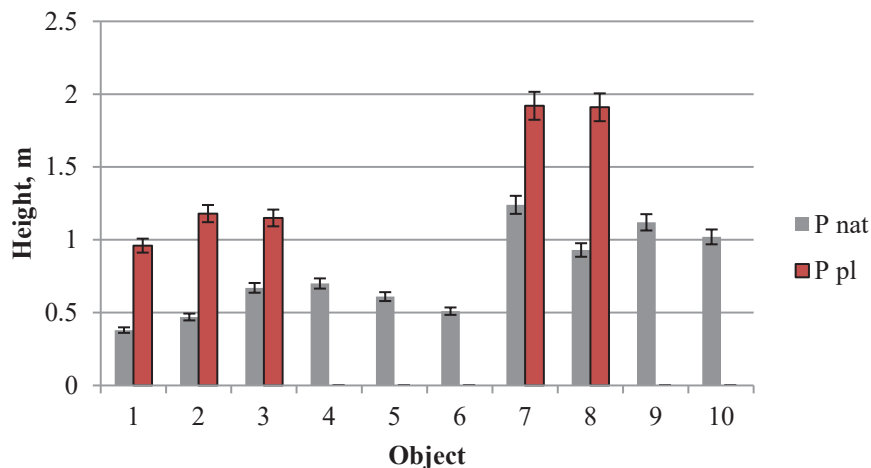


Figure 3. The average height of trees for both naturally regenerated and planted trees. Mean values are shown \pm SE. Abbreviations: P nat – naturally regenerated pines, P pl – planted pines.

Tree height analysis in the research sites. The tree height analysis shows what height the new generation trees have reached in the research sites after shelterwood cutting in *Myrtillosa* and *Hylocomiosa* forest types with different regeneration methods. The average height of trees for both naturally regenerated and planted trees is shown in Fig. 3.

In the six sites (felled in 2012 and 2013), tree heights were lower than in other four sites (felled in 2009). It can be seen that in the sites where Scots pines were planted, they were higher than the naturally regenerated pines growing in the same site. The difference in height is due to the fact that selected saplings are more productive than naturally regenerated ones, they have higher genetic quality, and both containerised and bare root plants have well-developed and wide root system as well as species proportional roots and shoots, which allow the tree to fully use nutrient and water resources.

The basal area of the remaining stand has a significant influence on the height of seedlings. When the basal area of the stand is larger, the height of the plants decreases. The negative impact of the increasing basal area on the tree height can be explained by the fact that in the meantime not only the new generation has taken root and grown, but also the shelter stand has increased. For the remaining trees of the stand after shelterwood cutting, immediate root growth can be expected, but the increment of the trunk volume is not observed immediately after cutting, and this period lasts from 2 to 4 years (Jakobsson, 2005). After continuous shelterwood cuttings carried out in Latvia, in most cases during the first two years after felling there has been an additional increment of the remaining stand, which is a part of the increment of the stand resulting from the impact. In its turn, the maximum of the

reduced additional growth in *Vacciniosa* is reached in 5–7 years, while in *Myrtillosa* and *Hylocomiosa* the maximum is reached in 3–4 years (Liepa, 1996; Zdors, 2015).

After shelterwood cutting, the feeding conditions of the remaining trees improve, the competition between the trees decreases and the light conditions improve, consequently the increase in the growth of the remaining trees in the stand can be expected. Considering that the research has shown the reduced additional maximum growth increment in *Myrtillosa* at the age of 3–4 years after performing shelterwood cutting, it is reasonable to assume that in the sites 9 years after felling, the maximum of the reduced additional increment has already been reached and the increment of the mature trees has significantly increased.

The research in Latvia has proved that the competition between young trees begins to appear at the age of 4–6. When this age has been reached, the tree crowns gradually close and the roots of the trees also begin to compete with each other (Jansons, 2008). Analysis of variance shows a significant negative effect of basal area on the height of new generation trees ($p=0.000$). This is due to the fact that 9 years after cutting, competition between the younger generation trees begins to increase, while the remaining trees in the stand have filled the growing space and start to negatively affect the growth of the new generation pine trees by reducing the amount of light in the felled areas. Timely performed subsequent cut improves the development of both planted and naturally regenerated plants (Nilsson *et al.*, 2006). Since the height of the trees in the sites 9 years after cutting shows a decrease at a larger basal area, it can be concluded that there is a need for the subsequent shelterwood cut in these stands.

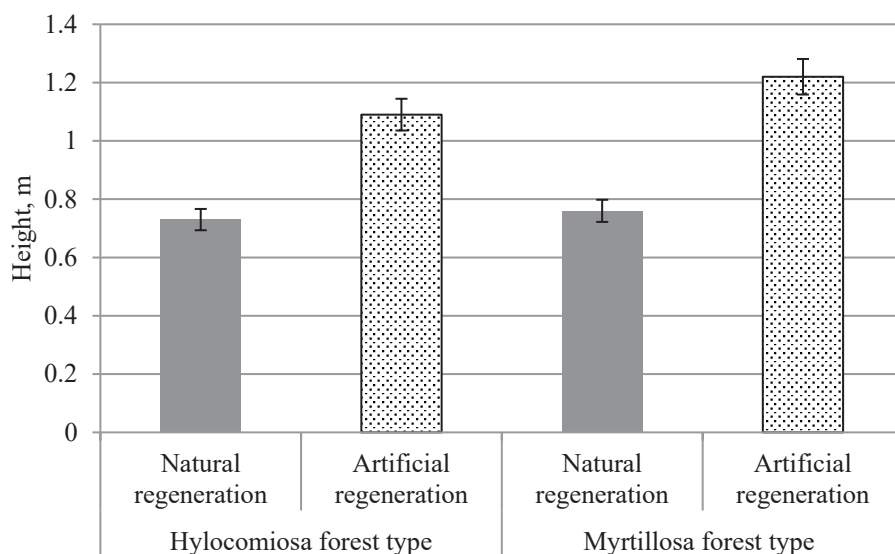


Figure 4. The height of trees by types of natural and artificial regeneration in the felling sites of the year 2013. Mean values are shown \pm SE.

The differences in the height of new generation trees by types of regeneration in the felling sites of the year 2013 can be seen in Fig. 4.

Variance analysis in both *Myrtillosa* and *Hylocomiosa* with 95% probability indicates that significant height differences are caused by the choice of the regeneration method ($p=0.000$), while the basal area of the remaining stand is not significant ($p=0.340$). In both *Myrtillosa* and *Hylocomiosa*, like previously – in the shelterwood cuttings of 2009, the height of artificially regenerated trees was observed to be higher than that of naturally regenerated trees, indicating the ability of planted trees to produce more rapid height increment in the first years of life after planting, irrespective of forest type. The height of naturally regenerated trees in *Hylocomiosa* is insignificantly lower than that of naturally regenerated trees in *Myrtillosa*. Although *Hylocomiosa* is a more fertile forest type than *Myrtillosa*, the height of planted pine trees in the latter is not significantly lower than in *Hylocomiosa* forest type. As it has been found, the reduced additional increment in *Myrtillosa* and *Hylocomiosa* started within 3–4 years after shelterwood cutting. In the cuttings of 2013, no significant impact of basal area on plant height was observed, thus the light conditions in the felled areas were sufficient and did not adversely affect pine growth. Under *Hylocomiosa* forest type, light conditions improve after cutting, and on fertile soils an increased shading by herbaceous plants is forming. The frequency of weeding depends on this shading and should be planned accordingly: to improve the growing conditions of the plants, it is necessary to schedule the weeding at least once a year, but if the shading of herbaceous plants is

large, tending should be performed twice a year. If weeding is not performed, much of the available nutrients and water are consumed by herbaceous plants, thus impeding the growth of young trees (Skudra & Dreimanis, 1993). As the height of the trees in *Hylocomiosa* is lower than in *Myrtillosa*, it is reasonable to assume that after shelterwood cutting there has not been sufficient weeding.

Conclusions

1. Estimated by the number of trees after shelterwood cutting, most sites should not be considered successfully regenerated; additional planting or scarification of soil is required which can improve the natural regeneration.
2. In all the sites both in *Myrtillosa* and *Hylocomiosa*, after shelterwood cutting it was observed that the height of artificially regenerated trees is significantly higher than the height of naturally regenerated trees, indicating the ability of planted pines to produce more rapid height increment in the first years of life, regardless of forest type.
3. The basal area of the remaining stand has a significant negative impact on the height increment of naturally regenerated and planted pines, and it indicates the need for the subsequent shelterwood cut to be performed.
4. Although *Hylocomiosa* is a more fertile forest type than *Myrtillosa*, the height of the planted pine trees in *Myrtillosa* is higher than in *Hylocomiosa*, where, after shelterwood cutting, no sufficiently intensive weeding has been performed in both forest types.

Acknowledgements

The study was carried out within the framework of the research 'Improvement of Growth Process Models' of Latvian State Forest Research Institute

'Silava' and was supported by the grant of project of Latvia University of Life Sciences and Technologies 'Implementation of LLU research programme'.

References

- Barbeito, I., Lemay, V., Calama, R., & Cañellas, I. (2011). Shelterwood systems within a multiscale framework. Regeneration of Mediterranean *Pinus sylvestris* under two alternative shelterwood systems within a multiscale framework. *Canadian Journal of Forest Research*, 41(2), 341–351. DOI: 10.1139/X10-214.
- Strand, M., Löfvenius, M.O., Bergsten, U., Lundmark, T., & Rosvall, O. (2006). Height growth of planted conifer seedlings in relation to solar radiation and position in Scots pine shelterwood. *Forest Ecology and Management*, 224 (3), 258–265. DOI: 10.1016/j.foreco.2005.12.038.
- Donis, J. (2015). Mežaudžu augšanas gaitas un pieauguma noteikšana, izmantojot pārmērītos meža statistiskās inventarizācijas datus (Determination of growth rate and growth of forest stands using remeasured forest statistical inventory data). Salaspils: Latvijas Valsts Mežzinātnes institūts 'Silava'. (in Latvian).
- Gaudio, N., Balandier, P., Perret, S., & Ginisty, C. (2011). Growth of understorey Scots pine *Pinus sylvestris* saplings in response to light in mixed temperate forest. *Forestry: An International Journal of Forest Research*, 84 (2), 187–195. DOI: 10.1093/forestry/cpr005.
- Jakobsson, R. (2005). Growth of retained Scots pines and their influence on the new stand. Doctoral thesis. Umeå, Swedish University of Agricultural Sciences: *Acta Universitatis Agriculturae Sueciae* 34.
- Jansons, Ā., & Džeriņš, A. (2008). Scots pine (*Pinus sylvestris* L.) stand phenotypic parameters depending on its juvenile stand density. *LLU Raksti*, 20 (315), 66–75.
- Liepa, I. (1996). *Pieauguma mācība* (The study of increment). Jelgava: LLU. (in Latvian).
- Matthews, J.D. (1991). *Silvicultural Systems*. Oxford: Clarendon Press.
- Nilsson, U., Örlander, G., & Karlsson, M. (2006). Establishing mixed forests in Sweden by combining planting and natural regeneration – Effects of shelterwoods and scarification. *Forest Ecology and Management*, 237, 301–311. DOI: 10.1016/j.foreco.2006.09.053.
- Nyland, R.D. (2016). *Silvicultural concepts and applications*. 3rd edition. USA: Waveland Press.
- Sharma, R.P., & Breidenbach, J. (2015). Modeling height-diameter relationships for Norway spruce, Scots pine and downy birch using Norwegian national forest inventory data. *Forest Science and Technology*, 11(1), 44–53. DOI: 10.1080/21580103.2014.957354.
- Skudra, P., & Dreimanis, A. (1993). *Mežsaimniecības pamati* (The base of forestry). Rīga: Zvaigzne. (in Latvian).
- Valkonen, S. (2000). Effect of retained Scots pine trees on regeneration, growth, form and yield of forest stands effect of retained scots pine trees. *Investigación agraria. Sistemas y recursos forestales*. 9 (1), 121–146. DOI: 10.5424/680.
- Zdors, L. (2015). Kokaudzes struktūras un apsaimniekošanas režīmu ietekme uz parastās priedes (*Pinus sylvestris* L.) atjaunošanos vienlaidus un grupu pakāpeniskajās cirtēs (Impact of tree stand structure and management regimes on the regeneration of continuous pine (*Pinus sylvestris* L.) in continuous and group fellings). Jelgava: LLU. (in Latvian).
- Zdors, L., & Donis, J. (2017). Evaluating the edge effect on the initial survival and growth of Scots pine and Norway spruce after planting in different size gaps in Shelterwood. *Baltic Forestry*, 23(2), 534–543.
- Zdors, L., Šņepsts, G., & Donis, J. (2017). Stem volume increment after group shelterwood cutting in Scots Pine stands in *Myrtillosa* forest type. *Baltic Forestry*, 23 (2), 463–470.

EVALUATION OF PRODUCTIVITY AND COSTS OF MALWA FOREST MACHINE IN SANITARY FELLINGS IN LATVIA

*Agris Zimelis¹, Santa Kalēja¹, Sergey Ariko²

¹Latvian State Forest Research Institute 'Silava', Latvia

²Belarusian State Technological University, Belarus

*Corresponding author's email: agris.zimelis@silava.lv

Abstract

The topicality of the study is determined by the increasing demand for sanitary felling services currently mainly provided by manual work. Harvesting using hand-held motor instruments is a physically hard work whose costs are increasing rapidly, but labor availability is declining. In sanitary cuttings, additional complications are caused by the use of conventional machinery in harvesting, which necessitates the creation of wide (4 m) technological corridors and significantly increases the proportion of damaged remaining trees in a stand (according to past studies, a set of middle-class forest machines in thinning of spruce stands results in 4–5% of damaged trees, but in pine stands – in approximately twice less damaged trees than in spruce stands). The compact class forest machines in thinnings result in mechanical damage to not more than 1% of remaining trees. During field trials in sanitary felling 9329 trees were felled. The average productivity working in one shift is 5.35 m³ h⁻¹ with average stands 10 cm. The cost of harvester's productive hour is 92 € but of a forwarder it is 78. The compact class forwarder creates significantly smaller impact on the soil by reducing ruts depth and soil compaction, which is especially important in sanitary fellings and extraction of seed trees in regenerated areas.

Key words: Malwa, sanitary felling, productivity, costs.

Introduction

The total area of sanitary fellings in Latvia in 2012–2017 was 74.5 thousand ha (average 14.9 thousand ha per year), excluding sanitary clear felling, resulting in 1.7 million m³ of timber (on average 0.35 million m³ per year). Converting to an area units extracted stock in this period was 23.5 m³ ha⁻¹. About half of the area of sanitary fellings has been extracted in state forests, the rest – in private and municipal forests. Seed tree extraction in 2012–2017 occurred in 1.2 thousand ha area, resulting in 0.2 million m³ of timber (238 ha and 39 thousand m³ per year in average). Selective landscape fellings are recorded in the Forest State Registry data since 2014. On average, 0.3 thousand ha are extracted per year in the landscape harvests, producing 3.3 thousand m³ (10 m³ ha⁻¹ on average) (CSP, 2018; Valsts meža dienests, 2019; Zemkopības ministrija, 2018). The thinning and regenerative felling of short-rotation forest plantations will increase in the coming years when short-rotation woody plants planted in the last decades will reach the age of economic use.

Sanitary fellings should be carried out if the impact of one of the risk factors has been recorded – biotic (cervids, bark beetle etc.), abiotic (wind, wet snow etc.) and anthropocentric one. An essential role for the carrying out of these fellings is damage caused by cervids game whose impact is essential (Rūba, Miežīte, & Luguza, 2014; Šņepsts *et al.*, 2018), and wind resulting in significant natural disturbances (Donis *et al.*, 2020; Snepsts *et al.*, 2020; Krisans *et al.*, 2020).

The aim of the study is to determine productivity and prime cost of harvesting and forwarding with a set of Malwa harvesting machines in selective fellings.

Materials and Methods

The study has been implemented at Forest Research Station, Jaunkalsnavas municipality. In the study, data were collected from 9 forest compartments. The criteria for selection of stands in the sanitary felling is conformity with the following conditions – in spruce and pine forest stands, where the proportion of the dominant tree species is > 60% and extractable stock at least 10 m³ ha⁻¹, trees damaged or felled by wind-throw or insect-damaged trees, the average DBH of the felled trees up to 10 cm, the length of the strip road < 300 m.

The remaining stand in the study is intended to be monitored in the long term, so permanent circular plots are established using the National forest inventory methodology. Plot centers are marked by wooden poles that stay at least 60 cm above the ground and, additionally, with red color blowing 1/3 of the pole length. Measurements of the DBH of trees are carried out by holding a caliper gauge ruler relative to the center, measured trees are marked by pushing on them the color point, which is focused on the plot center. The tree height is measured as the distance from the root collar to the top with an uncertainty of ± 0.5 m. Where an electronic hypsometer is used for measurements; the measuring instrument is calibrated before performing the work.

Templates developed for data collection contain general information on the measured stand, the worker and the date of execution of the work in sanitary cuttings. The forms are filled before and after sanitary felling. To make it easier for the worker to fill in the data, the boxes to be filled are stained according to the required plot radius. In the collars, the damage has to indicate the injury of the measured

tree if it is externally visible. Separate notes can be added of insect damages, dead laying trees and fallen trees (after strong wind some trees are fallen). To estimate the number of trees in the understorey that can significantly affect productivity rates, all trees in the plot are counted and an average height noted.

In sanitary cuttings, plots are placed on the longest felling diagonal. The first plot is placed with a center of 30 m from the edges. The smooth deployment of the plots is planned on a felling design by on the longest diagonal. Plot area is 200 m² (R 7.98 m). In the plot, trees are measured by species by separately dividing – pine, spruce, birch, aspen, black alder, grey alder, hard deciduous tree species combined; similarly, other soft deciduous tree species are combined too. Stem diameter is measured at 1.3 m from the root collar. The average is measured by a tree for which 1.3 m is larger or equal to 3 cm. For the construction of the height curve, height is determined by the species 1 tallest, 1 for shorter and 2 medium-height trees represented in the plot. If there are only individual trees of certain species in the plot, the height has to be measured for all of them.

Eleven work elements related to direct work and 3 elements related to other work operations have been identified for the logging process working time records. Working elements for time studies are:

1. Information fields:
 - 1.1. Working cycle number;
 - 1.2. Diameter of processed tree, DBH, cm;
 - 1.3. Various notes, travel, strip-road etc.
2. Working time:
 - 2.1. Reaching for tree with crane;
 - 2.2. Positioning of felling head;
 - 2.3. Cutting of tree;
 - 2.4. Delimiting and bucking;
 - 2.5. Log moving and stacking;

- 2.6. Undergrowth cutting;
- 2.7. Time spent on driving into a stand;
- 2.8. Time spent on leaving a stand;
- 2.9. Other non-standard operations;
- 2.10. Time spent on activities not related to harvesting;
- 2.11. Conversations with forest owner.

The notes indicate the reasons for working breaks and other activities. Work time records do not include machine preparation for work that takes approximately 1 hour per day, but the work time records include the lubrication of moving parts carried out during the shift. The amount of fuel consumed for the cost calculation was carried out using the meter AIS Systems.

Data processing is carried out in RStudio. The Shapiro-Wilk Normality test is used to find out whether the data are consistent with normal distribution. The distribution of the number of felled trees in the average grades is described using quartiles by dividing the dataset into equal parts where 25% of the data volume represents the smallest values, 50% median, 75% represents the highest values. Cost calculation is done using a cost model published by S.Kalēja (Kalēja *et al.*, 2018).

Results and Discussion

The diameter of felled trees ranges from 3 to 30 cm. The smallest processed tree has an average diameter of 3 cm, 25% of processed trees has 7 cm diameter, 50% or median has diameter of up to 10 and 75% of trees has a diameter up to 12 cm. The proportion of felled trees are divided by the diameter classes (Figure 1). According to the studies carried out so far, the productivity is significantly reduced if extracted trees have a diameter less than 6 cm (Lazdiņš *et al.*, 2016; Zimelis, Kalēja, & Okmanis, 2019).

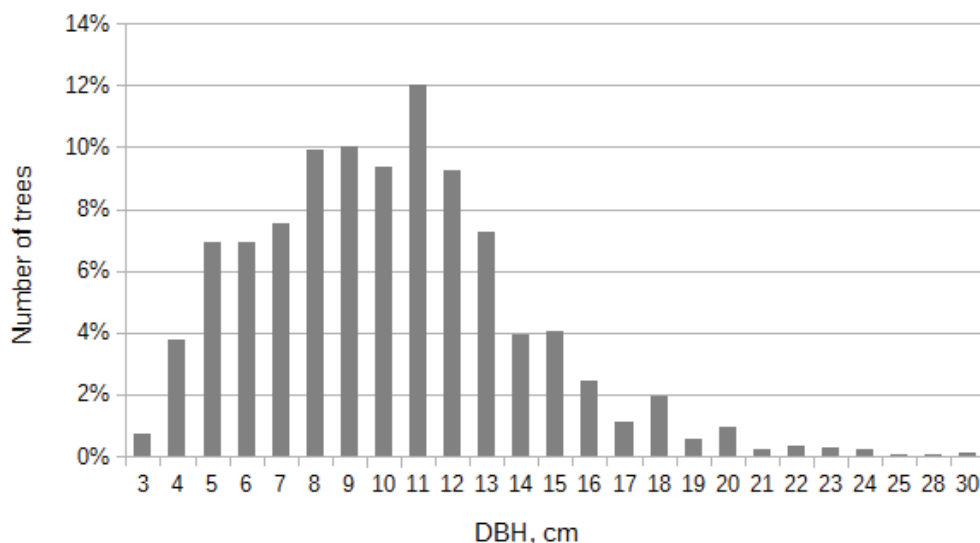


Figure 1. Diameter distribution of trees in sanitary felling.

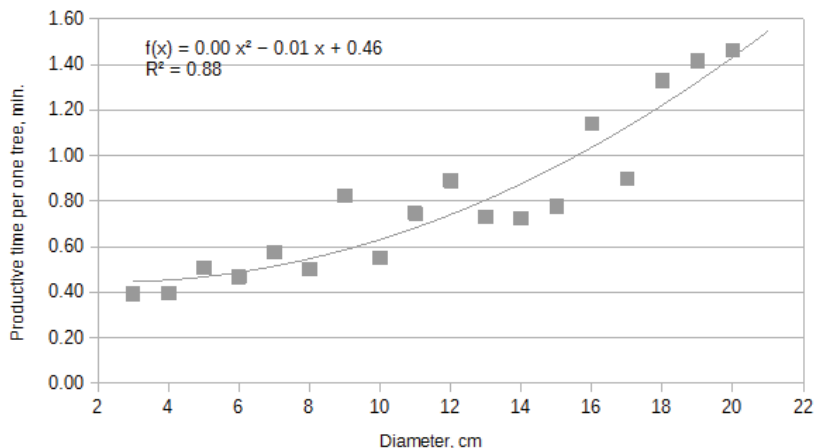


Figure 2. Productive time depends on tree dimensions.

Harvesting productivity in sanitary felling at an average tree of 10 ± 4 cm is $5.35 \text{ m}^3 \text{ h}^{-1}$, number of treated trees per hour is 85 ± 19 . Similar results have also been achieved in other studies where the productivity achieved in thinning is around $4.5 \text{ m}^3 \text{ h}^{-1}$ (P.S. Mederski, 2006; P. Mederski *et al.*, 2018). Such results are associated with technical capabilities of single grip harvesters, which determine that time to process a tree does not have a linear correlation with dimensions of tree; therefore, the dimensions of the trees to be processed have a significant impact on productivity (Figure 2).

Opposite impact of dimensions of trees on the productivity rate and number of trees processed per hour is shown in Figure 3. A reduction in the number of trees processed per hour appears when the diameter of extracted trees reaches 12 cm, which is associated

with time consumed for pruning operation, which amounts to 30% of the total working time.

When analyzing productivity of different forest machine operators, a significant (<0.05) difference is found. The first operator's average productivity is on average $6.2 \text{ m}^3 \text{ h}^{-1}$ processing 96 trees per hour, the second operator's productivity is $3.95 \text{ m}^3 \text{ h}^{-1}$, treating 69 trees per hour. The significant differences in productivity are combination to different work planning and experience working with a harvester. The second operator is planning work tree by tree, whereas the first operator plans harvesting order of 5–8 trees.

The test results used in the calculations are indicators of harvesting and delivery, the load size of the logs and the average forwarding distance. The cost calculations use average productivity indicators for

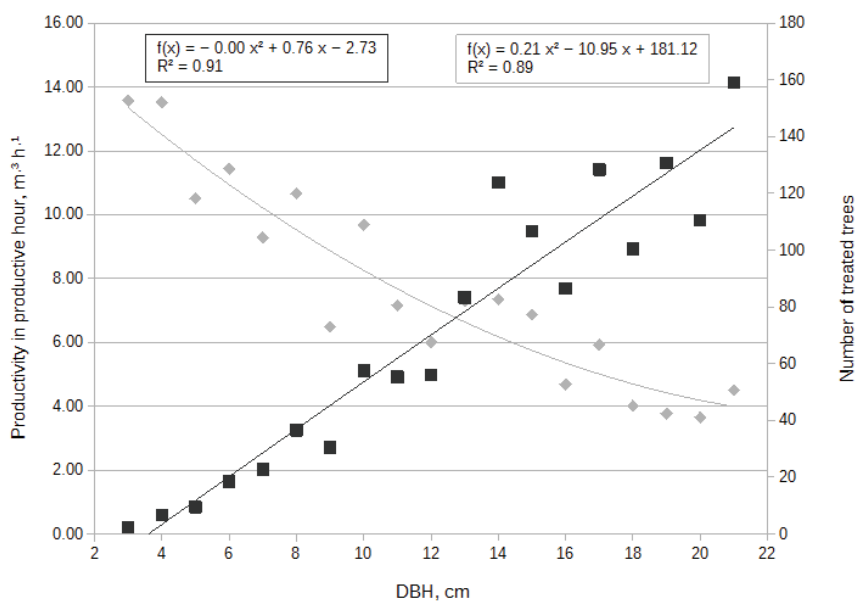


Figure 3. Relationships between productivity and number of cut trees depending on diameter.

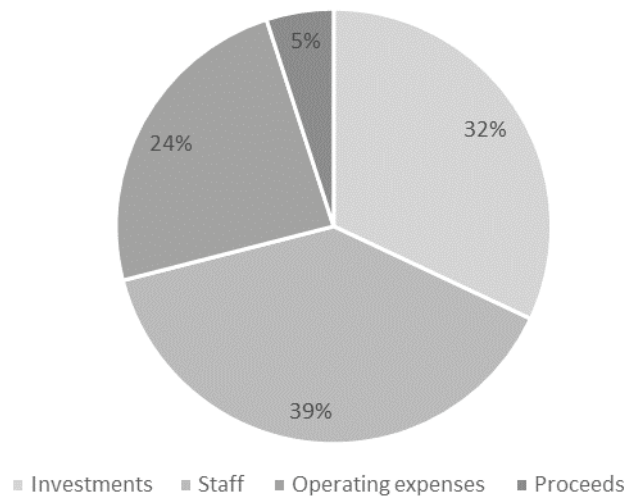


Figure 4. Different positions of harvesting costs.

harvester and forwarder. Direct and indirect harvester costs in all scenarios are the same. The average annual cost of Malwa harvester is 146 000 €. The most of the cost is operational costs, which include variables and part of fixed cost (insurance, taxes). Staff costs are the biggest expense position (38.9% of the total cost, Figure 4).

The salary rate of the harvester and forwarder operator use in calculation is 11 € per hour. Similarly, the calculations assume that harvester operators work in one shift for 7 hours. The total number of productive working hours of harvester per year, according to the assumptions, is 1232. Cost of harvester's productive

hour is 92 €. Harvesting costs with Malwa harvester at average productivity and sawn tree dimension rates are 21 € m⁻³. Fuel consumption in harvesting is 1.2 L m⁻³. The average annual cost of Malwa loading is 123 000 €. The calculations assume that forwarder operator performs work in two shifts (duration of a shift 7 hours). The cost of the productive time of the forwarder is 78 € per hour. Fuel consumption per 1 m³ is 1.0 L. Cost of round wood production and forwarding with Malwa machines in the trials were 34 € m⁻³ (Figure 5). In similar studies, forwarder costs are significantly lower (Petaja, Muižnieks, & Kalēja, 2017; Spinelli & Magagnotti, 2010). If the total number

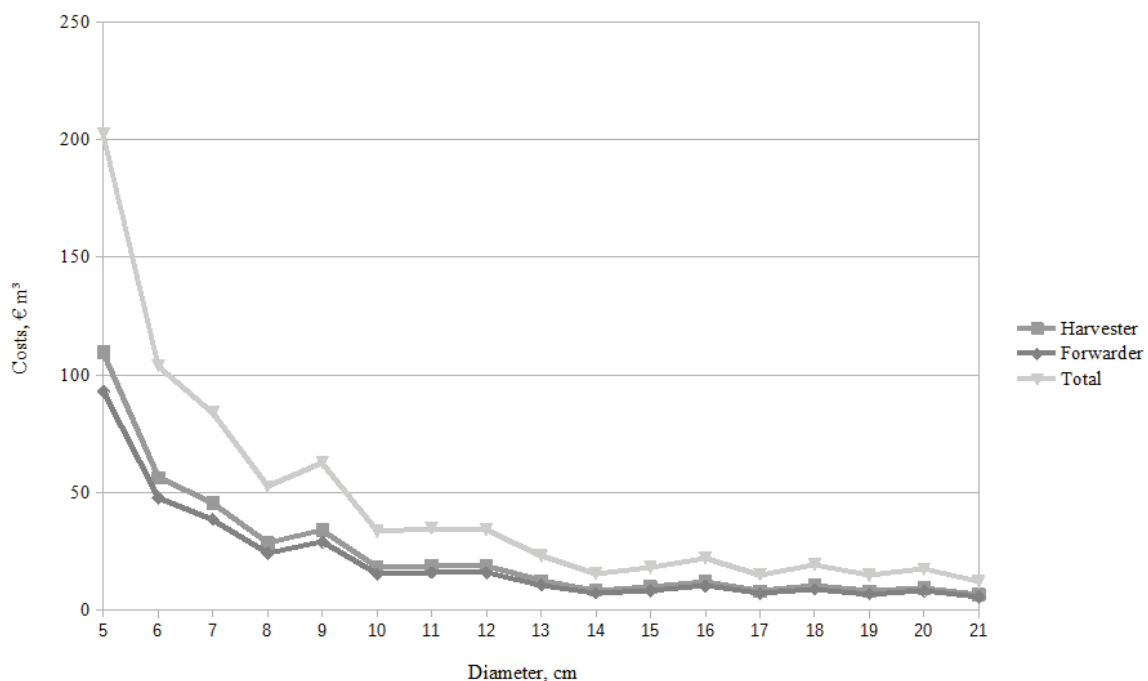


Figure 5. Costs in sanitary felling.

of shifts from the current one shift to two shifts per day is increased, the production cost would decrease to 21 € m⁻³. There is insufficient experience in operations of Malwa harvesters; therefore, operational costs may be significantly overestimated by application of a middle-class harvester and forwarder maintenance costs.

Conclusions

1. In sanitary felling, maintenance in one shift, the cost of timber preparation is 34.10 € m⁻³, increasing the number of shifts to two, the cost of timber preparation can be reduced by 60%.
2. Average productivity in sanitary cuttings is 5.35 m³ h⁻¹, at an average tree in DBH 10 cm.

3. The number of trees processed per working hour, which is a notable indicator of the harvester performance in sanitary cutting, ranged on average from 53 to 150. The highest number of trees processed per hour is a small dimension trees from DBH 3 to 6 cm.

Acknowledgements

The study was implemented within the scope of the Forest Sector Competence Centre of Latvia – No 1.2.1.1/18/A/004 ‘Approbation of non-standard harvesting solutions in non-conventional felling times’.

References

- CSP (2018). Centrālās statistikas gada grāmata, 2018. (Statistical yearbook of Latvia 2018). Rīga: Centrālā statistikas pārvalde, ISBN 978-9984-06-513-7. (in Latvian).
- Donis, J., Saleniece, R., Krisans, O., Dubrovskis, E., Kitenberga, M., & Jansons, A. (2020). A financial assessment of windstorm risks for Scots pine stands in hemiboreal forests. *Forests* 2020, 11, 566. DOI: 10.3390/f11050566.
- Snepsts, G., Kitenberga, M., Elferts, D., Donis, J., & Jansons, A. (2020). Stem damage modifies the impact of wind on Norway spruces. *Forests* 2020, 11(4), 463. DOI: 10.3390/f11040463.
- Krisans, O., Saleniece, R., Rust, S., Elferts, D., Kapostins, R., Jansons, A., & Matisons, R. (2020). Effect of bark-stripping on mechanical stability of Norway spruce. *Forests*, 11, 357. DOI: 10.3390/f11030357.
- Kalēja, S., Lazdiņš, A., Zimelis, A., & Spalva, G. (2018). Model for cost calculation and sensitivity analysis of forest operations. *Agronomy Research*, 16(5), 2068–2078. DOI: 10.15159/AR.18.207.
- Lazdiņš, A., Prindulis, U., Kalēja, S., Daugaviete, M., & Zimelis, A. (2016). Productivity of Vimek 404 T5 harvester and Vimek 610 forwarder in early thinning. *Agronomy Research*, 14(2), 475–484. Retrieved January 21, 2020, from http://agronomy.emu.ee/wp-content/uploads/2016/05/Vol14_nr2_Lazdins.pdf.
- Mederski, P.S. (2006). A comparison of harvesting productivity and costs in thinning operations with and without midfield. *Forest Ecology and Management*, 224(3), 286–296. DOI: 10.1016/j.foreco.2005.12.042.
- Mederski, P., Venanzi, R., Bembenek, M., Karaszewski, Z., Rosińska, M., Pilarek, Z., ... Surus, M. (2018). Designing Thinning Operations in 2nd Age Class Pine Stands—Economic and Environmental Implications. *Forests*, 9(6), 335. DOI: 10.3390/f9060335.
- Petaja, G., Muižnieks, E., & Kalēja, S. (2017). Efficiency of Vimek 610.2 forwarder and its impact on soil in forest thinning. In *Rural Development* (p.6). Aleksandras Stulginskis University. DOI: 10.15544/RD.2017.176.
- Rūba, J., Miezīte, O., & Luguza, S. (2014). Impact of risk factor management on the sanitary condition of Norway spruce (*Picea abies* [L.] Karst.) pure stands in Latvia. *Journal of forest science*, 60(5), 181–189. DOI: 10.17221/4/2014-JFS.
- Šnepsts, G., Bigača, Z., Desaine, I., Jansons, J., Donis, J., Strēlnieks, K., ... Krišāns, O. (2018). Characteristics of damages in Norway spruce stands. In *Research for Rural Development* (pp. 65–71).
- Spinelli, R., & Magagnotti, N. (2010). Performance and cost of a new mini-forwarder for use in thinning operations. *Journal of Forest Research*, 15(6), 358–364. DOI: 10.1007/s10310-010-0193-x.
- Valsts meža dienests, (2019). 2018. gada Publiskais pārskats. (Public Overview 2018). Rīga. Retrieved January 21, 2020, from https://www.zm.gov.lv/public/files/CMS_Static_Page_Doc/00/00/01/54/24/VMD_Publiskais_parskats_2018_.pdf. (in Latvian).
- Zemkopības ministrija. (2018). *Meža nozare skaitļos un faktos (Latvian Forest sector in facts & figures)*. Rīga. Retrieved January 24, 2020, from https://doi.org/https://www.zm.gov.lv/public/ck/files/skaitli&fakti_LV_2017.pdf. (in Latvian).
- Zimelis, A., Kalēja, S., & Okmanis, M. (2019). Complex forest management system based on small size forest machines. *Engineering for Rural Development*, 1, 6. Retrieved February, 14, 2020, DOI: 10.22616/ERDev2019.18.N021.

EVALUATION OF COMPLIANCE OF EXISTING FOREST MACHINE INFORMATION SYSTEMS FOR THE IMPLEMENTATION OF THE STANDARD STANFORD 2010

*Aigars Strubergs¹, Andis Lazdins², Linards Sisenis¹

¹Latvia University of Life Sciences and Technologies, Latvia

²Latvia State Forest Research Institute 'Silava', Latvia

*Corresponding author's email: aigars.strubergs@llu.lv

Abstract

The aim of the study is to clarify the compliance of machinery information systems used by Latvian logging service providers with the requirements of the Forest Machine Data and Communications Standard StanForD 2010. For determining the number of logging machines and structure registered in Latvia, data from the State Technical Control Agency of Latvia (VTUA) has been used. This dataset includes 2094 registered machinery units from which 1663 units recorded as harvesters and forwarders are distributed for data processing. Using the national AS Latvian State Forests (LSF) database, where 541 machinery units have been recorded, of which 239 harvesters and 302 forwarders, it is determined what and how many machines already use the standard StanForD 2010, how many machines can implement it and which machines are not suitable for the implementation of StanForD 2010. The study showed that the VTUA register does not fully reflect the true quantity of harvesting machines in Latvia and does not provide information about the use of machines. The LSF data provide reliable information on the possibilities of using StanForD 2010 in harvesters in national forests. From the harvesters working in the country's forests, 52% of the machines uses the StanForD 2010 standard. Work should be continued to clarify the possible use of the standard in the machines working in private forests. Similarly, work should be continued with dealers of harvesting machines to identify models for which it is possible to adjust the StanForD 2010 standard and what the cost of adapting the indicative information systems is.

Key words: forest harvesting, StanForD 2010, efficiency.

Introduction

In recent decades, Scandinavian or, in other words, assortment technology is widely applied in logging all over the world. With this technology, logging takes place using two types of machines: harvesters (cut-to-length – CTL), which carry out felling, delimiting and bucking in the assortments on the felling site and forwarders of a certain length that take these assortments from the felling site to the top yard. When a certain amount of assortments has been loaded in the yard, the delivery of the assortments is organised to the bottom-end yard or processing company with timber trucks. Therefore, the circulation of exact information between the provider of logging services, round wood transporters and contractors is becoming very current.

As information technologies and their applications evolve, such development has also influenced harvesting machines. The development began in the eighties when Robert Bosch GmbH developed and began introducing CAN (Cartoon Area Network) into the management of technology machines (CAN in Automation, 2011). Later CAN technology was used in logging machines to automatically record machine parameters when work was done, without direct human participation. Automatic data recording can also result in more accurate accounting of machine and operator working time, reducing the need for manual working time accounting and improving its accuracy as machines become faster and conduct work time records manually, a researcher can no longer track all activities such as indicate the average of the sawn

tree and species (Peltola, 2003). For such records a special data logger connected to the machine control system by a CAN cable was developed for. In the mid-eighties, machine data communication standard StanForD was developed specifically for logging machines, it collected data of machines, products and a series of other data, and was important for machine and human work analysis at that time. The development of harvesting machines and information systems is demonstrated in Table 1 (Palander *et al.*, 2013).

Each logging machine manufacturer had developed its own control systems according to the StanForD standard for data file processing, hence, to process the machine data, such programs needed to be purchased from the machinery manufacturer. In most cases, the software of different manufacturers is completely or partially incompatible, which makes the processing of data from different manufacturer programs quite difficult. The problem also arises when a harvesting company has purchased and operates several manufacturer harvesting machines, then data processing requires each manufacturer's data processing programs and additional purchasing of manufacturers' licenses. In addition, programs may have limitations on data processing and storage. Of course, you can transfer data into a .pdf format, however, with such a large amount of data, the processing can be time consuming and these files are not usable for further automated data processing.

Over time, the first version of StanForD became outdated, many variables lost their relevance and there was a need for other content data. In 2010 a new

Table 1

The development of time studies in harvester operations (Palander *et al.*, 2013)

	Decades				
	1970's	1980's	1990's	2000's	2010's
Timing Techniques					
Digital watch					
Field computer					
Video technique					
Automated data collector					
Research Topic					
Machine technology					
Determination of piecework rates					
Cutting environment					
Harvester – forwarder team					
Operators skills in man – machine systems					
Time Study Approaches					
Nomenclature					
StanForD					
Process – data models					
Adaptive work study methods					

StanForD 2010 standard was finished and introduced (Arlinger *et al.*, 2012). The new standard works in an open .xml format and no special, expensive program is required to open a file. Changes in the file types compared to the old standard are large because it was based on felling, while the new one is based on a time scale that allows a much more accurate analysis of the data.

Latvian logging companies have started the implementation of StanForD 2010 and are learning its capabilities. Evaluating research by scientists from other countries, it is clear that the implementation of the standard and, in particular, the scope of application, is in need of a lot of work. The study of research results shows that StanForD 2010 may be successfully used in the analysis of productivity of harvester operator and machine utilization rate, and the automatically acquired data is reliable because studies have shown that differences from manually derived data are not significant (Brewer *et al.*, 2018). Consequently, the analysis of the data obtained can make a significant contribution to improvement of operator skills, hence the productivity would increase and harvesting costs decrease (Strandgard, Walsh, & Acuna, 2012).

According to State Joint Stock Company Latvian State Forests (LSF) data the forwarders used in Latvia are not using StanForD 2010. However, a literature review reveals that StanForD 2010 data are used in the world to analyse productivity of forwarder operators (Eriksson & Lindroos, 2014; Manner *et al.*, 2016).

The aim of this study is to assess the readiness of the Latvian Logging Park to implement the StanForD 2010 standard and to identify priority actions for ensuring technical readiness in private and state owned forests.

Materials and Methods

Data from the State Technical Control Agency of Latvia (VTUA) and from the LSF are used for the analysis of harvesting machines used in Latvia. A survey of Latvia's most popular harvesting machine brand dealer is conducted to clarify the conformity of different models to the standard StanForD 2010.

All purchased or purchased overseas and transported equipment units are recorded in Latvia. The register includes the following information: a machine type, brand, model, factory number, release year, engine power registration date, and details of owner and holder (legal person or private person). Tractor units are removed from the register if they are written off or sold abroad. In Latvia, legislation does not provide an annual technical inspection of harvesting machines, hence the VTUA does not have the data required for the study of how many hours the machine works per year, which would give information whether their machine works or not, and whether this machine exists in Latvia at all.

Data collected from VTUA are used to identify the total number and structure of logging machines recorded in Latvian enterprises or to individuals

(harvester, forwarder, skidder, etc.). Harvesting machines in the form of a chart are divided by the decades of release years, determining the age structure of the machine model lines, which allows to discuss the possibilities of implementing StanForD 2010. Next, the machines from this database recorded in Latvia, are grouped by machine type (harvesters, forwarders, u.t.t) and according to their readiness for the implementation of StanForD 2010. In this study, compliance with the implementation of StanForD 2010 will be evaluated only for harvesters. Information on forest machinery registered at VTUA till November 30. 2019 is used in the study.

Using the LSF service provider database (updated in 01 February 2020) the structure of machinery used in harvesting can be determined by brands and model lines. The LSF database provides information about machine type (harvester, forwarder), brand, model, release year, in which type of felling it works (main, tending, damaged tree felling); for harvesters additionally: if it supports StanForD 2010 or not. This information provides an idea of actual workload of harvesting machine that can also be attributed to private forests, creating a picture of the amount of machinery used in harvesting. Based on calculations, different harvesting machines work in private and state forests, meaning, double amount needs twice as many machines. Harvesters are separately divided by brand, each brand is divided by release year, and the release year determines how many machines of each brand support or already use the StanForD 2010 standard.

Surveying of dealers of logging machines was clarified, from which release year an update of information systems can be carried out for each brand according to the StanForD 2010 standard.

Results and Discussion

Using the logging machinery database recorded by VTUA, it has been established that 2094 harvesting machinery units have been recorded on November 30. 2019 in Latvia, including: harvesters, forwarders, skidders and agricultural tractors transferred to

forwarders. The oldest machinery unit recorded as a forest machine in VTUA records was produced in 1959. Analysing recorded logging machines by release decades shows that 0.4% of recorded machines were produced from 1959 to 1970, 3.4% of machines were produced from 1971 to 1980, 21.1% of machines were produced from 1981 to 1990, 14.0% of machines were produced from 1991 to 2000, 35.8% of machines were produced from 2001 to 2010 and 25.3% of machines were produced from 2011 to 2019 (Figure 1).

When grouping the machines by type, it has been found that 1132 forwarders have been recorded in Latvia, of which the oldest was manufactured in 1959, and 531 harvesters, of which the oldest was produced in 1988, 2 harwarders and 428 other forest machines with no type specified.

The database of logging machines recorded by VTUA is not an objective data source for the analysis of machines working in Latvia, because a large part, especially the oldest machines may have been dismantled, unused but not removed from the records. However, some middle-aged and younger machines are not used in connection with significant technical damage, may have been rented to other companies in Latvia or abroad and are located outside the territory of Latvia, while preserving registration in Latvia. Therefore, the exact number of harvesting machines in Latvia cannot be estimated. Similarly, it is not in all cases possible to obtain accurate information from the database about what type and brand logging machine has been recorded because only the release year and the type, forest machine, is mentioned. Information is incomplete for both old and last decade produced machines. It is also not possible to obtain information from the VTUA registration data if these machines are supported by the StanForD 2010 standard. It shall be ascertained after the release year and the machine factory number at the dealership of the specific machine.

The distribution of harvesters recorded by VTUA by machine brands (Figure 2).

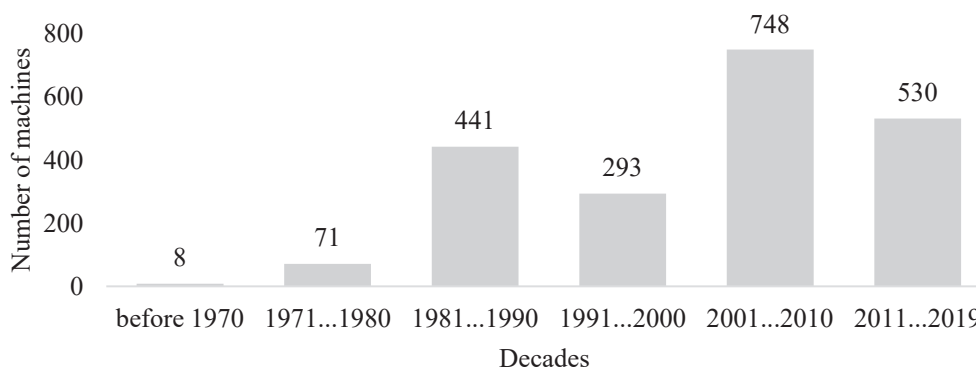


Figure 1. Distribution of logging machines recorded in Latvia by decades of the release.

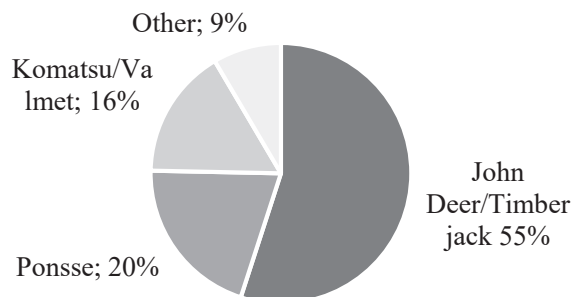


Figure 2. Distribution of harvesters by machine brands.

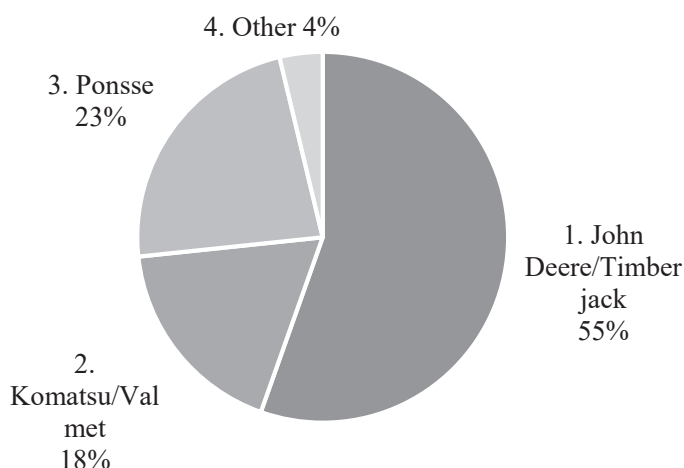


Figure 3. Distribution of harvesters by manufacturers.

Given that the harvesting amount and structure in cutting types in private and state owned forests is comparable, more accurate information on actually used harvesting machines in the country can generally be obtained by assessing which harvesting machines are used in LSF felling areas.

Using LSF data on machinery units involved in harvesting operations, information is obtained on how and what harvesting machines are already working by using the StanForD 2010 standard and what is the potential application structure of harvesting machines in private forests. During this extrapolation, thinning and final felling are analysed separately. The State Forest Service data on logging in state and other forests from 2015 to 2020 years have been used to analyse harvesting volume.

LSF StanForD 2010 data are used for production records and harvester .hpr and .hqr files are applied to the harvester quality control. In this regard, there is a lack of reasonable information to what extent such information is used by private forest owners.

According to LSF data in areas managed by the company, logging companies working on contract basis use 239 harvesters and 302 forwarders. According to

the information provided by LSF, the StanForD 2010 standard is used only in harvester reports.

The distribution of the harvesters working in LSF by manufacturers is illustrated in Figure 3. Most widely used are John Deere/Timberjack harvesters – 133 machinery units, followed by Ponsse harvesters – 54 machinery units, Komatsu/Valmet harvesters – 43 machinery units and 4% of other manufacturers machinery including three Logset harvesters, two Ecolog harvesters and one of each by Jacrac, Case, Rottne and Vimek.

From the 239 harvesters used in LSF harvesting, the StanForD 2010 standard is supported by 125 machines (Figure 4). Looking at the distribution of harvesters by manufacturers and support of StanForD 2010, it is evident that LSF harvesting companies conduct work with 133 John Deere/Timberjack harvesters of which 72 supports StanForD 2010, 54 Ponsse harvesters of which the standard is supported by 32 machines, while from 43 Komatsu/Valmet machines standard is supported by 17.

As each machine brand has its own management system and software, the analysis needs to look at each brand of the machine separately.

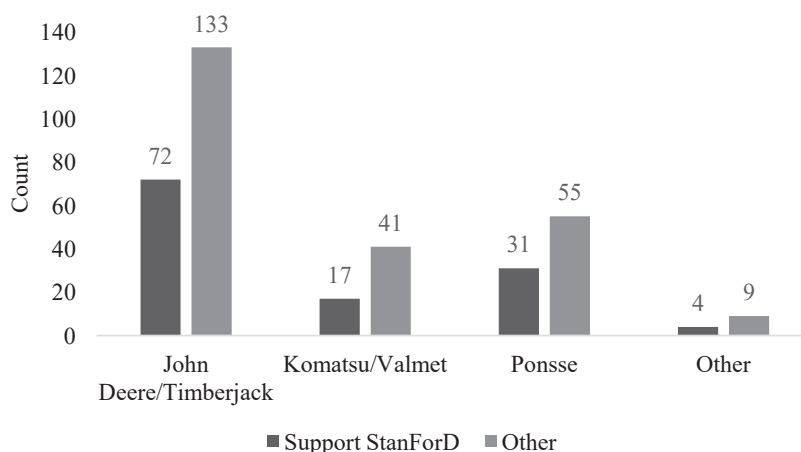


Figure 4. Harvester distribution by manufacturer and StanForD 2010 support (units).

The most popular brands of forest machines in Latvia (John Deere/Timberjack, Ponsse and Komatsu/Valmet) are evaluated in the study. Distribution of machines of the brands by the release year and information on the support to StanForD 2010 is provided in Table 2.

Logging machines were equipped with systems supporting StanForD 2010 standard in factory

starting from the model year 2009-2010. According to Figure 4 and Table 2, LSF employs 229 John Deere / Timberjack, Ponsse and Komatsu / Valmet harvesters and 120 or 52% of them supports the StanForD 2010 standard. LVM employs 152 harvesters manufactured after 2009, including 96 harvesters (63%) with information systems supporting StanForD 2010 standard. A survey of equipment dealers demonstrated

Table 2

Distribution of harvesters (number of units) of the most popular brands by production years

Model year	John Deere/Timberjack		Ponsse		Komatsu/Valmet	
	Count	Support standart	Count	Support standart	Count	Support standart
2000	1	-	-	-	-	-
2001	-	-	-	-	1	-
2002	-	-	1	-	-	-
2003	1	-	-	-	-	-
2004	2	1	-	-	1	-
2005	4	-	2	-	3	-
2006	14	2	1	-	4	-
2007	12	3	4	-	-	-
2008	14	5	3	-	3	1
2009	7	4	3	1	-	-
2010	13	10	1	-	1	1
2011	9	7	4	-	7	2
2012	9	6	3	-	5	3
2013	6	6	2	2	-	-
2014	9	7	3	2	6	4
2015	3	2	3	3	4	2
2016	7	5	-	-	2	-
2017	3	2	6	4	-	-
2018	3	2	8	8	-	-
2019	9	9	11	11	4	4

that each brand of harvesters manufactured after 2009 may have different costs for updating the information system. The final cost depends on the amount of work to be performed and depends on the equipment of the harvester. Harvester information systems are constantly being developed and improved, so software updates are needed. For harvesters after 2015, a software update is usually sufficient, while harvesters manufactured between 2009 and 2014 may require a software replacement. For harvesters manufactured before 2009, not all brands will have a technically feasible and cost-effective adaptation of the information system to support StanForD 2010. For these harvesters, upgrading the system will include replacing the computer, control unit, and wiring.

The Table 2 shows that most of the LSF working harvesters, or 52% of the 2010 model year, are supported by StanForD 2010. Survey of the machinery dealers, concludes the most popular harvester brands used in Latvia, which are on average younger than 2010, require relatively little changes in the software StanForD support.

As logging amounts in public and private forests are similar and 44% of the harvesters recorded in VTUA work in the state forests, it can be assumed that some of the other harvesters work in private forests and older harvesters are not used at all. If in the national forests after the release year 2009, 37 % of the working machines need software update, it can theoretically be assumed that, at the same harvesting amounts, the software update of harvesters working in private forests is required by the same percentage of machines.

References

- Arlinger, J., Möller, J., Sorsa, J.A., & Räsänen, T. (2012). *Introduction to StanForD2010*. Structural descriptions and implementation recommendations. Skogforsk. 74 p. [Published draft]. Retrieved February 20, 2020, from <https://www.skogforsk.se/contentassets/1a68cdce4af1462ead048b7a5ef1cc06/stanford-2010-introduction-150826.pdf>.
- Brewer, J., Talbot, B., Belbo, H., Ackerman, P., & Ackerman, S. (2018). A comparison of two methods of data collection for modelling productivity of harvesters: manual time study and follow-up study using on-board-computer stem records. *Annals of Forest Research*, 61(1), 109–124. DOI: 10.15287/afr.2018.962.
- CAN in automation (2011). *CAN history*. Retrieved February 28, 2020, from <https://www.can-cia.org/can-knowledge/can/can-history/>.
- Eriksson, M., & Lindroos, O. (2014). Productivity of harvesters and forwarders in CTL operations in Northern Sweden based on large follow-up datasets. *International Journal of Forest Engineering*. 25 (3), 179–200. DOI: 10.1080/14942119.2014.974309.
- Manner, J., Palmroth, L., Nordfjell, T., & Lindroos, O. (2016). Load level forwarding work element analysis based on automatic follow-up data. *Silva Fennica*, Vol. 50. No. 3, article id. No. 1546. 19 p. DOI: 10.14214/sf.1546.
- Palander, T., Nuutinen, Y., Kariniemi, A., & Väättäin, K. (2013). Automatic Time Study Method for Recording Work Phase Times of Timber Harvesting. *Forest Science*. Vol. 59, Issue 4, 472–483. DOI: 10.5849/forsci.12-009.
- Purfürst, F.T. (2010). Learning curves of harvester operators. *Croatian Journal of Forest Engineering*, 31, 89–97.

Conclusions

1. Stanford 2010 is supported by the majority of harvesters produced after 2009 (44% of the total number of registered harvesters), and for this machine category it is sufficient to update or replace the software in order to ensure standard compliance, accordingly, with the lowest costs. The assessment of the compliance of older harvesters points to a great uncertainty. Machinery units that can theoretically support StanForD 2010 need a replacement of the information system, unless it has already been done.
2. State Technical Control Agency of Latvia shall have information on the logging machines at its disposal, that reflects the general technical characteristics of the machines registered in Latvia (brand, model line, age), which gives an estimate of the number of harvesters supporting StanForD 2010, but this system does not include information on the use of machines and their actual location.
3. According to the harvester records working in Latvian State Forests fellings, 52% of the machinery units support the StanForD 2010 standard, but in most machinery units this standard support programme is not used or not fitted. Accordingly, Latvian State Forests service providers need a significant contribution of resources and work hours to implement StanForD 2010 in production.
4. The study shows that nearly all of the most popular brand harvesters recorded in Latvia are suitable for the implementation of StanForD 2010, but in order to objectively describe the suitability of harvesters working in private forests for the implementation of StanForD 2010, further research is required.

- Peltola, A. (2003). IT-time for Mechanised Forest Work Study. 2nd Forest Engineering Conference 12–15 May 2003, Växjö, Sweden. Skogforsk Arbetsrap. 536, 107–112.
- Strandgard, M., Walsh, D., & Acuna, M. (2012). Estimating harvester productivity in *Pinus radiata* plantations using StanForD stem files. *Scandinavian Journal of Forest Research*. Vol. 28, Issue 1, 73–80. DOI: 10.1080/02827581.2012.706633.

ORGANOSOLV DELIGNIFICATION OF RESIDUAL PLANTATION WILLOW BARK AFTER EXTRACTIVE REMOVAL

*Matiss Pals^{1,2}, Liga Lauberte², Alexandr Arshanitsa², Laima Vevere², Vilhelmine Jurkjane², Galina Telysheva²

¹Latvian State Institute of Wood Chemistry, Latvia

²University of Latvia, Latvia

*Corresponding author's email: matiss232@gmail.com

Abstract

Plantation willows are commonly grown plants which are widely used for energetic purposes that does not correspond completely to its potential. To fully integrate this resource into biorefinery scheme, it is necessary to study optimal conditions of willow bark processing, aimed for separation of bark components, their comprehensive characterization and profitable practical application. Extraction of secondary metabolites is well known approach for bark processing. But the separation of the main cell wall components including lignin from the residual biomass is less studied. In this work plantation residual willow bark after extractives separation by two different solvents (acetone and ethanol-water) was used as a feedstock for *Organosolv* delignification. Effect of temperature and catalyst used on the yield and properties of lignin isolated from residual bark by ethanol-water treatment was studied. It was possible to obtain pure lignin with high yields (up to 41%) that has the potential to be used for bio-plastic producing. Insoluble residue after delignification was carbohydrate rich (up to 80%) feedstock allowing its practical use for bioethanol producing.

Key words: plantation salix, proanthocyanidins, lignin, delignification, biorefinery.

Introduction

Willows are one of the most common woody plants grown on plantations for energy purposes (Szcukowski *et al.*, 2012). Although their potential is very wide, willows are not currently being used to their full potential. Willow bark contains many valuable extracts, such as salicin, its derivatives and condensed tannins, mainly proanthocyanidins. The qualitative and quantitative composition of Willow bark extracts varies depending on the used willow breed, age, growing area and conditions. Multiple studies have been described, marking it as a source of polyphenolic compounds with strong antioxidant properties (Krasilnikova *et al.*, 2018). However, to fully utilize willow bark as a resource, it is necessary to study the possible processing pathways for the residue left after extractives removal. The resulting bark residue after extraction can be used as a potential raw material for the separation of lignin and carbohydrates, which may further serve as feedstock to produce various high added value products. Lignin can be used as a renewable feedstock for polyurethane material or epoxide resin production (Hu, Zhang, & Lee, 2018; Mathew *et al.*, 2018) and/or as a natural antioxidative additive. Carbohydrates can be used as a source of glucose for production of bioethanol, furfural and its derivatives (Takkellapati, Li, & Gonzalez, 2018; Naik *et al.*, 2010). In recent years a lot of attention is being paid to *Organosolv* delignification methods. When compared to other more commonly used methods of delignification, *Organosolv* delignification is more in terms of green chemistry, it allows to separate lignin in sufficiently high yields and allows to obtain low condensed lignin that more closely resembles its native state. Although *Organosolv* delignification is studied quite extensively, it has not been widely

applied in processing of tree barks (Koumba-Yoya & Stevanovic, 2017; Huijgen *et al.*, 2014). In present work the delignification of residual willow bark in ethanol-water media in the presence of acid catalysts was studied in terms of lignin's yield, the presence of admixtures and hydroxyl groups content that will open the possibilities of lignin modification.

Materials and Methods

Materials and chemicals

All chemicals were of analytical grade and were purchased from Merck and used without further purification.

Samples

Plantation willow samples (variety 'Klara') were 3 years of age when taken from the plantation in Skriveri region in Latvia. Bark removed by a handle debarking was air dried (moisture content was 6%) and then was ground to a smaller particle size (<2mm) using Retch-100 cutting mill. Prior to use, the milled willow bark was stored in plastic bags in a freezer at -18 °C.

Extractives removal as a pre-treatment of biomass

Two methods of extraction were compared. First one is Soxhlet extraction with acetone with accordance to TAPPI T-204 standard method. Around 10 g of ground willow bark was weighted into extraction thimble and inserted into Soxhlet apparatus with 100 mL of acetone. Total extraction time was 8 hours. Second method of extraction was performed with 50% (v/v) ethanol/water solution under reflux. Around 25 g of ground willow bark was placed into round bottom flask and inserted into oil bath with temperature set to 80 °C. Solution was heated under reflux for 2 hours. After that liquid was removed and fresh solvent was added. This procedure was repeated

Table 1

Used delignification conditions

Abbreviation	Extraction method	Catalyst	t, °C
K1	Extraction with acetone	4,5 mmol FeCl ₃	190
K2	Extraction with 50% ethanol	4,5 mmol FeCl ₃	190
K3	Extraction with acetone	9 mmol FeCl ₃	215
K4	Extraction with 50% ethanol	9 mmol FeCl ₃	215
K5	Extraction with acetone	15 mmol H ₂ SO ₄	190
K6	Extraction with 50% ethanol	15 mmol H ₂ SO ₄	190

4 times and solutions removed were combined. After each extraction, solvent was removed using rotary evaporation, and around 100 mL of water was added. After that extracts were freeze dried using HETO POWER Dry PL3000 freeze-dryer.

Analysis of separated extracts

Folin–Ciocalteu method for determining total phenolic content in extracts and acid-butanol method for determining total proanthocyanidin content in extracts was performed as described in literature (Vieito *et al.*, 2018). Identification of individual compounds in extracts were done using Waters Acquity H-Class UPLC system (USA) equipped with quaternary gradient pump, autosampler, temperature-controlled column department, diode array detector and Synapt G2-Si high resolution mass spectrometer (USA). CSH C18 (1.7 μm, 2.1 x 100 mm) column was used. Mobile phase consisted of 0.1% formic acid in water (A) and acetonitrile (B). Used ESI ions source, operated in negative ionisation mode. Identification of individual compounds were done by comparing obtained high resolution mass spectra with information available in Metlin database (Guijas *et al.*, 2018).

Organosolv delignification

25 g of extractives free willow bark, 250 mL of 50% (v/v) ethanol/water solution and given amount of catalyst were loaded into 1 L PARR 4848 high pressure reactor, followed by heating and mixing under pressurized conditions (Table 1)

After 90 minutes of treatment, delignified biomass was separated from liquor by filtering. Liquor was concentrated in rotary evaporator and lignin was precipitated in 600 mL of ice-cold water, then filtered and washed with water till pH=5 was reached. Remaining water-soluble fraction was freeze dried.

All acquired fractions were weighted after drying to determine full mass balance.

Analysis of separated fractions

Klason and acid soluble lignin content were determined using standard method (TAPPI T-222) (TAPPI, 2011). Py-GC/MS was carried out as described previously by colleges (Ponomarenko *et al.*, 2014).

The monomeric sugars content in biomass was determined by the gas chromatography (GC-FID) method as described in (Blakeney *et al.*, 1983) with slight modifications. 10 mg of the sample was loaded into a screw tube, 0.125 ml of 72% H₂SO₄ was added and the mixture was incubated at room temperature for 3 h. Then, 3.5 ml of distilled water was added and then the mixture was incubated at 101 °C for 3 h. The cooled sample was neutralized with 0.32 ml of NH₄OH and 0.1 ml of methyl-α-D-glucopyranoside solution (20 mg ml⁻¹) was added as an internal standard. 0.2 ml of the sample was taken, and 1 ml of 2% NaBH₄ solution in dimethyl sulfoxide was added and the mixture was incubated at 40 °C for 90 min. The excess of NaBH₄ was decomposed by adding 0.1 ml of glacial acetic acid. 2 ml of acetic anhydride and 0.2 ml of 1-methylimidazole were added to the solution and incubated at 40 °C for 10 min. Then, 5 ml of water was added, and the solution was extracted with 1 ml of CH₂Cl₂ for 1 minute. The CH₂Cl₂ layer was collected for GC analysis.

Results and Discussion

Extraction results

The yield of extractives' results as well as the total phenolics and total proanthocyanidins content in them are shown in Table 2. All experiments were done in triplicate, results shown with standard deviations.

Table 2

The yield of extractives and their characteristic

Extraction method	Amount of extractives, %	TPC, %	PAC, %
Extraction with Acetone	17.8±0.3	37.7±0.5	23.2±0.5
Extraction with 50% EtOH	36.1±0.5	52.9±0.6	27.9±0.4

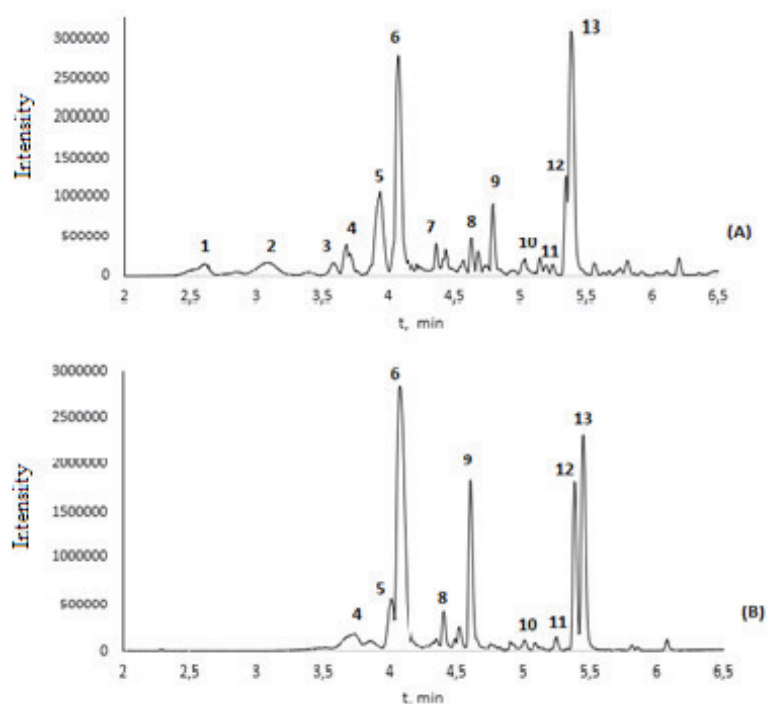


Figure 1. BPI chromatograms of separated extracts. (A) 50% v/v ethanol/water extract, (B) acetone extract.

Comparison of the extraction results shows that using 50% v/v ethanol/water as extraction solvent yielded 2 times more extractives than when using acetone. Although acetone is a semi-polar extraction solvent and can extract a broader range of compounds (11), this result indicates that the willow bark extractives are predominantly polar compounds.

Individual compounds were identified in the obtained extracts using the UHPLC-MSMS system. The obtained chromatograms are shown in Figure 1. The results show that the extract obtained with 50% v/v ethanol/water has more individual compounds, with a greater presence of both proanthocyanidins and salicylates.

Table 3

Identification of individual compounds

No.	[M-H] ⁻	M ²	Identification
1	305.066	261.075	Gallocatechin
2	593.130	305.057	Epicatechin – gallocatechin dimer
3	881.193	289.076	Epicatechin – gallocatechin trimer
4	135.045	117.049	4-Hydroxyphenylacetaldehyde
5	577.135	289.077	Epicatechin dimer
6	289.073	245.082	Epicatechin
7	401.140	383.023	Flavonoid glycoside
8	415.161	383.092	
9	473.166	293.084	
10	423.402	405.118	Salicortin
11	493.229	403.241	Flavonoid glycoside
12	421.128	331.142	
13	569.167	447.224	Acetyl-tremulacin

Table 4

Composition of initial and extracted bark samples

Sample	KL, %	ASL, %	Cellulose content, %	Ash content, %
Untreated bark	21.3±0.8	4.7±0.2	21.4±0.4	2.15±0.05
Extracted with acetone	26.0±0.9	3.8±0.2	23.4±0.7	2.44±0.06
Extracted with 50 % ethanol	29.2±1.5	3.47±0.14	24.9±0.5	2.32±0.06

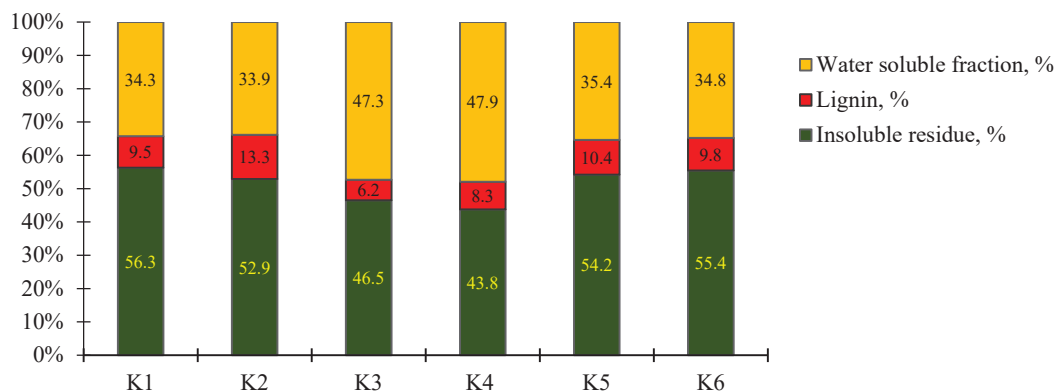


Figure 2. Mass balance of separated *Organosolv* fractions (abbreviations shown in Table 1).

In total 13 peaks were identified. The results obtained show that the predominant compounds of both extracts are proanthocyanidins as well as their monomers, epicatechin and galocatechin. Various flavonoids and their derivatives, as well as salicin derivatives such as salicortin and acetyl-tremulacin, are also observed. Peak identification is shown in Table 3 with observed $[M-H]^-$ ion and most pronounced fragment ion M^2 .

Delignification of residual bark after extraction

For the residual bark after extractives removal, Klason lignin (KL), acid soluble lignin (ASL), cellulose and ash content were determined. All experiments were done in triplicate, results shown with standard deviations. Obtained results are shown in Table 4.

Obtained results show that residual bark after removal of extractives is a potential feedstock of lignin and cellulose obtaining, since these main components

are more concentrated in residual biomass. To separate individual components from residual bark after extractives removal, several delignification experiments were performed. Delignification conditions under study and abbreviation of samples are presented in Table 1. The mass balance of delignification processing as well as precipitated lignin yields on KL lignin content in biomass were calculated (Figures 2, 3).

It was shown that the yield of lignin in the case of delignification of residual bark after extractives removal by ethanol pre-treatment was higher in comparison with that obtained by delignification of acetone pre-treated bark (Figures 2, 3). According to the data (Koumba-Yoya *et al.*, 2017), this can be explained by partial deactivation of catalyst due to formation of stable complex with phenolic of non-lignin origination extraction of which from bark by acetone was less effective.

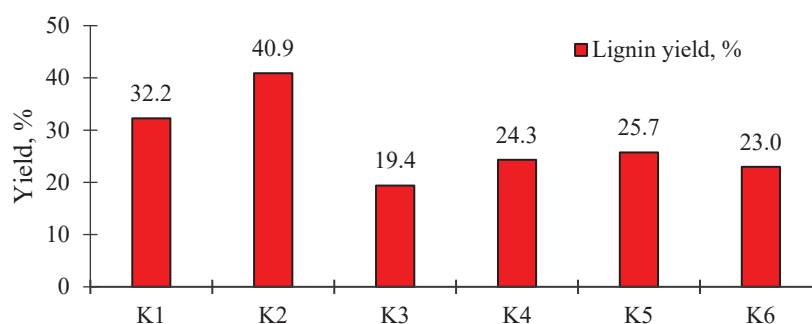


Figure 3. The yields of *Organosolv* lignin on KL content in biomass (Abbreviations shown in Table 1).

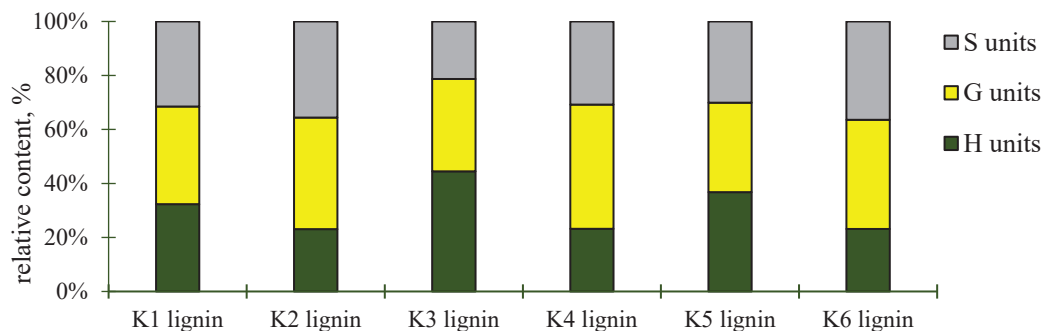


Figure 4. The relative content of lignin subunits in derived volatile products of lignin samples according to Py-GC/MS results.

The increasing of delignification temperature and amount of catalyst strongly promotes the transition of biomass components into the liquor. At higher temperature (215 °C) the yield of precipitated lignin is decreased, but the portion of products remaining in soluble state after lignin separation is increased significantly. Obviously, at high temperature solubilisation of hemicellulose and lignin in liquor is accompanied by their depolymerization. Noticeable higher positive effect of FeCl₃ catalyst in comparison with H₂SO₄ on the yield of lignin was observed for bark residual after water-ethanol extraction. It was similar for both catalysts in case of acetone extracted bark.

Analysis of obtained fractions

The KL content in precipitated lignins varied in the range of 90–64.2%. The lignin, isolated by delignification using FeCl₃ as a catalyst, contained less of non-lignin admixtures. This was proven by GC-FID method. For lignin samples (K1–K4), isolated using FeCl₃, the presence of carbohydrates admixtures was not observed. In lignin samples K5 and K6, isolated by sulphuric acid catalysed delignification, some content of carbohydrates was observed, (5.37% For K5 and 6.54% for K6), meaning their chemically bonded incorporation into the lignin matrix.

It was established that separated lignins are S/G/H types of lignin, but the relative portion of different lignin subunits in them is changed in comparatively wide range depending on delignification regimes that obviously will influence their transformation during further chemical modification (Figure 4). For example, it can be prognosticating that lignin (K3), separated using enhanced amount of FeCl₃ is characterized by the lower portion of methoxylated subunits, and therefore will be able for further undergoing of internal C-C condensation using free 3, 5 positions in aromatic ring. This transformation is not beneficial for further chemical modification due to decrease of heat mobility of polymeric chains. Such a type of lignin could be used as an active filler of thermosets due to action as a promoter of char formation enhancing the fire retardance properties of material. On the contrary, the K4 sample has the highest portion of methoxylated subunits in them indicating lower potential to self-condensation and therefore, high suitability for chemical modification and introducing in polymeric (polyepoxide, polyurethane) composition as a macromonomer. Other lignins take the middle between samples K3 and K4 samples position in terms of methoxylated lignin content in them.

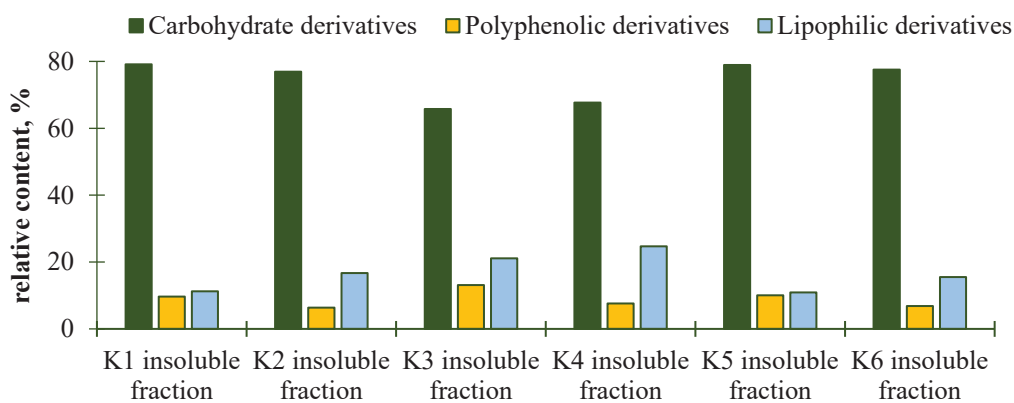


Figure 5. The relative content of main biomass components derived volatile products of residual barks samples after delignification according to Py-GC/MS results.

The yield of insoluble part of dignified bark consisted between 45–55% on DM of extracts free bark. Therefore, the study of its composition for search of further valorisation is an important task in view of biorefinery approach.

It was determined by Py-GC/MS that residual biomass contains mainly (70–80%) carbohydrate derivatives with some admixture of lignin and lipophilic compounds, obviously, consisted mainly of polyesters of suberin and paraffin (Figure 5). GC-FID method used for carbohydrate determination in these residues shows that after complete hydrolysis they contain only glucose, indicating that carbohydrate component of insoluble residue consists mainly from cellulose. The data of residual bark composition allow to characterize it as promising feedstock highly reached with cellulose in comparison with initial wood biomass, thus suitable for micro cellulose and/or bioethanol production. Due to presence of high calorific lipophilic compounds in residual bark biomass, application of it for heat and energy production can be recognized as one more direction of extractives free delignified bark valorisation.

Conclusions

1. The results obtained have shown that Plantation willow bark is a prospective renewable resource

References

- Blakeney, A.B., Harris, P.J., Henry, R.J., & Stone, B.A.A. (1983). Simple and Rapid Preparation of Alditol Acetates for Monosaccharide Analysis. *Carbohydr. Res.* 113(2), 291–299. DOI: 10.1016/0008-6215(83)88244-5.
- Guijas, C., Montenegro-Burke, J.R., Domingo-Almenara, X., Palermo, A., Warth, B., Hermann, G., Koellensperger, G., Huan, T., Uritboonthai, W., & Aisporna, A.E. (2018). METLIN: A Technology Platform for Identifying Knowns and Unknowns. *Anal. Chem.* 90(5), 3156–3164. DOI: 10.1021/acs.analchem.7b04424.
- Huijgen, W.J.J., Telysheva, G., Arshanitsa, A., Gosselink, R.J.A., & de Wild, P.J. (2014). Characteristics of Wheat Straw Lignins from Ethanol-Based Organosolv Treatment. *Ind. Crops Prod.* 59, 85–95. DOI: 10.1016/j.indcrop.2014.05.003.
- Hu, J., Zhang, Q., & Lee, D.J. (2018). Kraft Lignin Biorefinery: A Perspective. *Bioresour. Technol.* 247, 1181–1183. DOI: 10.1016/j.biortech.2017.08.169.
- Koumba-Yoya, G., & Stevanovic, T. (2017). Transformation of Sugar Maple Bark through Catalytic Organosolv Pulping. *Catalysts.* 7(10), 294. DOI: 10.3390/catal7100294.
- Krasilnikova, J., Lauberte, L., Stoyanova, E., Abadjieva, D., Chervenkov, M., Mori, M., De Paolis, E., Mladenova, V., Telysheva, G., & Botta, B. (2018). Oregonin from *Alnus Incana* Bark Affects DNA Methyltransferases Expression and Mitochondrial DNA Copies in Mouse Embryonic Fibroblasts. *J. Enzyme Inhib. Med. Chem.* 33(1), 1055–1063. DOI: 10.1080/14756366.2018.1476504.
- Mathew, A.K., Abraham, A., Mallapureddy, K.K., & Sukumaran, R.K. (2018). Waste Biorefinery. India: Elsevier. DOI: 10.1016/B978-0-444-63992-9.00009-4.
- Naik, S.N., Goud, V.V., Rout, P.K., & Dalai, A.K. (2010). Production of First and Second Generation Biofuels: A Comprehensive Review. *Renew. Sust. Energ. Rev.* 14(2), 578–597. DOI: 10.1016/j.rser.2009.10.003.
- Ponomarenko, J., Dizhbite, T., Lauberts, M., Viksna, A., Dobeļe, G., Bikovens, O., & Telysheva, G. (2014). Characterization of Softwood and Hardwood LignoBoost Kraft Lignins with Emphasis on Their Antioxidant Activity. *BioResources.* 9(2), 2051–2068. DOI: 10.15376/biores.9.2.2051-2068.
- Szczukowski, S., Tworkowski, J., Klasa, A., & Stolarski, M. (2012). Productivity and Chemical Composition of Wood Tissues of Short Rotation Willow Coppice Cultivated on Arable Land. *Rostl. Výroba.* 48(9), 413–417.

- that can be incorporated into biorefinery schemes for obtaining value products added of different use.
2. Both extracts isolated by acetone and 50% EtOH/water treatment of bark are rich with biologically active compounds - predominantly proanthocyanidins and salicin derivatives.
 3. Residual bark after extractives removal can be further used as a feedstock for delignification. High purity (up to 90%), carbohydrate admixtures free lignins can be obtained by delignification performed at 190–215 °C, using 50% ethanol/water solution in the presence of FeCl₃ as a catalyst.
 4. The isolated lignins have a potential to be used as a macromonomer in polyepoxide and polyurethanes compositions.
 5. Insoluble residue after delignification is highly enriched with cellulose (up to 80%) and could be used as a source of micro cellulose and/or hydrolysis feedstock, or as a solid biofuel source.

Acknowledgements

This study was financially supported by the Bio-economic grant 'LignoBark' from the Latvian State Institute of Wood Chemistry

- Technical Association of Pulp and Paper Industry. (2011). T222 Om-02 Lignin in Wood and Pulp. *TAPPI test methods*, 1–7.
- Takkellapati, S., Li, T., & Gonzalez, M.A. (2018). An Overview of Biorefinery-Derived Platform Chemicals from a Cellulose and Hemicellulose Biorefinery. *Clean Technol. Environ. Policy*. 20(7), 1615–1630. DOI: 10.1007/s10098-018-1568-5.
- Vieito, C., Fernandes, É., Velho, M.V., & Pires, P. (2018). The Effect of Different Solvents on Extraction Yield, Total Phenolic Content and Antioxidant Activity of Extracts from Pine Bark (*Pinus Pinaster* Subsp. *Atlantica*). *Chem. Eng. Trans.* 64, 127–132. DOI: 10.3303/CET1864022.

CHEMICAL PROPERTIES OF NEEDLES AS AN INDICATOR OF NUTRIENT STATUS OF FERTILIZED CONIFEROUS STANDS

*Ilze Karklina^{1,2}, Zaiga Anna Zvaigzne¹, Jēlena Stola¹

¹Latvian State Forest Research Institute ‘Silava’, Latvia

²University of Latvia, Latvia

*Corresponding author’s email: ilze.karklina@silava.lv

Abstract

Enhanced forest growth may respond to demand of woody resources and contribute to the climate change mitigation. Forest soil treatment with fertilizers, as well as drainage and thinning enhance forest growth. The analysis of needles is an established method in forest science to identify the nutrient status in the forest stand and need for forest soil enrichment with fertilizers. The aim of this research is to estimate the efficiency of forest soil enrichment with wood ash and ammonium nitrate in order to eliminate nutrient deficiency in forest stands. Forest soil was enriched with wood ash fertilizer or ammonium nitrate in 2016–2017. The current year needles were collected from fertilized and control plots, from three trees in each plot. The samples were collected in the period 2018–2019. Total nitrogen (g kg^{-1}), calcium (g kg^{-1}), magnesium (g kg^{-1}), and potassium (g kg^{-1}) were analyzed in the collected samples. The chemical properties of collected needles were compared at the individual object level to estimate the impact of fertilizer on forest stand. A statistically significant increase in the concentrations of potassium and phosphorus was detected in some plots treated with wood ash and ammonium nitrate. In addition, a correlation analysis conducted between the variables of chemical properties of needles and soil showed few significant correlations between nutrient content in needles and in soil samples.

Key words: wood ash, ammonium nitrate, nutrients, improvement of forest growth.

Introduction

Forest type and growth conditions characterize forest fertility. Forest stands on organic soils are often limited in nutrients; therefore, soil improvement with wood ash may compensate deficiency of particular elements (Jacobson, 2003). Still, the overall guidelines may not always be suitable for a particular region due to different geochemical and hydrological factors (Libiete *et al.*, 2017), and even to a specific forest stand because of a particular nutrient availability in a stand.

In Latvia, several studies of improvement of forest growth conditions and impact of forest management practices are carried out. The studies show a positive tree growth response in stands fertilized with wood ash (Okmanis, Kalvis, & Lazdina, 2018) and a long-term effect of initial fertilization of Norway spruce seedlings on stemwood volume (Jansons *et al.*, 2015). Furthermore, studies focus also on environmental impacts of treatments, e.g., nutrient concentration in soil water, groundwater and surface water – after harvesting of coniferous stands (Libiete *et al.*, 2017) and after fertilization and planting of a plantation (Bardule *et al.*, 2018). In the context of possible fertilization induced nutrient leaching and impact on chemistry of water, it is essential to estimate the nutrient status of forest stands. Chemical analyses of needles or leaves alongside with analyses of soil chemistry and visual estimation of canopy vitality are commonly used methods for the diagnosis of the nutrition status of a forest stand (Mandre, 2006). Current year needles are considered to be the main indicator of nutrition status, but chemical properties of previous year needles may also be useful for evaluation (Rautio *et al.*, 2017).

Nutrient availability in the soil of particular stand also has an impact on chemical properties of needles as an indicator of nutrient status (Saarsalmi & Mälkönen, 2001). Analysis of soil is also advisable for estimation of nutrient availability in a forest stand. Furthermore, it is suggested that nutrient content in soil is site-specific rather than dependent on a treatment, e.g., harvesting (Libiete *et al.*, 2019).

The forest soil fertilization can compensate the nutrient deficiency in forest stand, thus improving growth conditions of trees. Wood ash application generally increases pH and Ca and Mg concentration in forest floor (Ozolincius *et al.*, 2006), but higher experimental doses reduce moss layer (Ozolincius, Buozyte, & Varnagiryte-Kabasinskiene, 2007).

The chemical parameters of ash, especially the content of trace metals, as an impact of the combustion process on properties of wood have been a topic of interest in studies (Pitman, 2006). Moreover, the mobility and bioavailability (Vincevica-Gaile *et al.*, 2019) of nutrients released with wood ash fertilization are relevant topics of studies.

In the scope of bio-economy and efforts to minimize the waste disposal in landfills, the usage of wood ash as a forest soil fertilizer to compensate the nutrient deficiency could be a rational decision. According to The Regulation of the Cabinet of Ministers, No. 506 (Cabinet of Ministers of Latvia, 2015) wood ash can be classified as ‘other liming materials’ if the minimal neutralizing capacity as CaCO_3 equivalent is at least 20% of dry mass. State Plant Protection Service can cancel the status of waste if the wood ash material produced by a particular plant can fulfill the requirements stated by The Regulations No. 506.

The aim of the research was to evaluate the impact of forest soil improvement with fertilizers on tree nutrient status by estimating the changes of element concentrations in needles.

Materials and Methods

Study sites and treatment

In total, 18 experimental sites were established in coniferous forest stands managed by Joint Stock Company 'Latvia's State Forests' and the Research forest station (Table 1). The experimental sites are

divided in two groups with different treatment, namely, forest stands treated with wood ash and forest stands first treated with wood ash and next with ammonium nitrate. Each of the research objects has at least one control plot and one fertilized plot to evaluate the impact of forest soil treatment at the individual research object level. The study was conducted in 36 to 94 years old Scots pine (*Pinus sylvestris* L.) and Norway spruce (*Picea abies* (L.) H.Karst.) stands, including different forest site types.

Table 1

Description and treatment of experimental sites

Forest site type	Dominant tree species	Age of stand	Dose: t WA or N ha ¹	Fertilizer spreading	Date of treatment
wood ash treatment					
<i>Hylocomiosa</i> / dry mineral soil	Norway spruce	54	2 t WA	manually	11.2014
<i>Hylocomiosa</i> / dry mineral soil	Norway spruce	54	2 t WA	manually	11.2014
<i>Hylocomiosa</i> / dry mineral soil	Norway spruce	50	2 t WA	mechanically	05.2017
<i>Myrtillosa mel.</i> / drained mineral	Norway spruce	53	3 t WA	mechanically	10.2016
<i>Myrtillosa mel.</i> / drained mineral soil	Norway spruce	44	3 t WA	mechanically	05.2017
<i>Myrtillosa mel.</i> / drained mineral soil	Norway spruce	45	6 t WA	manually	12.2016
<i>Myrtillosa turf. mel.</i> / drained organic soil	Norway spruce	48	*4 and 8 t WA	manually	12.2016
<i>Myrtillosa turf. mel.</i> / drained organic soil	Scots pine	94	3 t WA	mechanically	02.2018
<i>Oxalidososa turf. mel.</i> / drained organic soil	Norway spruce	54	2 t WA	manually	11.2014
<i>Oxalidososa turf. mel.</i> / drained organic soil	Norway spruce	49	2 t WA	manually	11.2014
wood ash and ammonium nitrate treatment					
<i>Vacciniosa mel.</i> / drained mineral soil	Scots pine	66	3 t WA + 0.44 t N	mechanically	02.2017/07.2017
<i>Vacciniosa mel.</i> / drained mineral soil	Scots pine	65	3 t WA + 0.44 t N	mechanically	02.2017/07.2017
<i>Vacciniosa turf. mel.</i> / drained organic soil	Scots pine	59	3 t WA + 0.44 t N	mechanically	02.2017/07.2017
<i>Myrtillosa mel.</i> / drained mineral soil	Norway spruce	38	3 t WA + 0.44 t N	mechanically	02.2017/07.2017
<i>Myrtillosa mel.</i> / drained mineral soil	Norway spruce	36	3 t WA + 0.44 t N	mechanically	02.2017/07.2017
<i>Myrtillosa turf. mel.</i> / drained organic soil	Norway spruce	58	3 t WA + 0.44 t N	mechanically	02.2017/07.2017
<i>Vacciniosa turf. mel.</i> / drained organic soil	Scots pine	60	3 t WA + 0.44 t N	manually	02.2017/07.2017
<i>Oxalidososa turf. mel.</i> / drained organic soil	Norway spruce	54	3 t WA + 0.44 t N	mechanically	10.2016/07.2017

WA – wood ash

N – NH₄NO₃

* 4 t ha⁻¹ and 8 t ha⁻¹ spread in two treatment plots

Table 2

The content of nutrients in needles of Norway spruce, % of dry mass

Nutrient	Deficiency	Low	Optimal	High	Plentiful
Ca	<0.20	0.20-0.30	0.30-0.50	0.50-0.80	>0.80
Mg	<0.10	0.10-0.15	0.15-0.30	0.30-0.40	>0.40
K	<0.40	0.40-0.60	0.60-1.20	1.20-1.60	>1.60
P	<0.15	0.15-0.20	0.20-0.40	0.40-0.50	>0.50

Collection and analysis of samples

The samples of needles were collected after forest soil fertilization, in 2018–2019. Current year needles were collected from three trees at each plot, from the upper part of the canopies, or from five trees if the experimental site had only one control plot and one treated plot. In addition, soil samples were collected for the reference level before the fertilization of trial plots. Samples were taken from mineral soil level at the depths: 0–10 cm, 10–20 cm, 20–40 cm and 40–80 cm.

The needles were dried in an oven at the temperature of 70 °C and ground to a fine, homogeneous powder. The soil samples were air-dried, homogenized and sieved with 2 mm sieve according to standard ISO 11465:1993. To determine the nutrients Ca (g kg⁻¹), Mg (g kg⁻¹), K (g kg⁻¹) and P (g kg⁻¹), both samples were microwave digested (Mars 6 iWave, CEM) with 65% HNO₃. Needles' extracts were analyzed with Inductively Coupled Plasma Spectrophotometer (ICP-OES, iCAP 7200 Duo, Thermo Fisher Scientific) and soils extracts – with Flame Atomic Absorption Spectroscopy (FAAS, AAnalyst 200, Perkin Elmer).

Statistical analysis

We used Wilcoxon rank sum test with continuity correction (non-parametric test) to estimate differences between the control and the treated plots at the individual forest stand level. To characterize the impact of nutrient status in the soil on the chemical properties of needles, a Spearman correlation analysis was conducted between the same nutrients in needles and soil samples. The tests were conducted at a 95% confidence level, in program R (R Core..., 2018). In addition, the results were compared with the deficiency and optimum values of elements in needles of Norway spruce determined by Nollendorfs (2008) and used in Latvia (Table 2).

The concentration of nutrients in needles collected from Scots pine stands was compared with the optimal values (% of dry mass) determined by Kaposts and Saceniaks (1981): Ca 0.25–0.30%; Mg 0.09–0.10%; K 0.50–0.60%; P 0.14–0.15%.

Results and Discussion

Differences in nutrient concentration between fertilized and control plots

The mean values of nutrient concentration in needles collected from control and fertilized plots are

summarized in Table 4 and Table 5. Table 4 presents differences in chemistry of needles at the individual object level fertilized with wood ash.

At the individual research object level, there were elevated concentrations of calcium and magnesium in wood ash treated plots if compared with control plots. This tendency was observed also for potassium and phosphorus but to a lesser extent. In this trial group no statistically significant differences were detected; however, the tendency of elevated nutrient status in current year needles collected from wood ash treated plots was observed in a part of experimental objects.

If compared with the values given by Nollendorfs (2008), the calcium level in Norway spruce stands is optimal or even high without any deficiencies observed. However, the analysis of current year needles indicated low concentrations of magnesium and even deficiency of this element in particular stands. Similarly, in a part of Norway spruce stands potassium and phosphorus levels in the needles were optimal, but in several stands deficiency of these elements was detected. Still, needle nutrient level below optimal does not necessarily indicate that the tree growth is limited by this element (Jacobson, 2003).

The nutrient status in current year needles was above the optimum in the 54-years-old Scots pine stand, except for potassium. However, the concentration of potassium was optimal in wood ash fertilized plot, compared with the control plot, 'where there' was a deficiency of the element observed.

Interestingly, in the 45 and 48-years-old Norway spruce experimental objects treated with wood ash dose 6 t ha⁻¹, and 4 t ha⁻¹ in one trial plot and 8 t ha⁻¹ in another trial plot – in the second stand, respectively, a tendency of elevated concentrations of calcium, magnesium and phosphorus were observed, although no statistically significant differences were detected. This suggests that the nutrient uptake is limited by the capacity of trees. However, doses of 6 t ha⁻¹ may be recommended for plantations, where the wood ash enhances the growth of hybrid aspen (Bardule *et al.*, 2013).

The Table 5 represents differences in chemistry of needles at the individual object level, fertilized first with wood ash and next with ammonium nitrate.

Table 4

**Nutrient concentrations in needles from control and wood ash treated plots
(mean values ± standard error of the mean)**

Forest type	Tree species	Stand age	Plot	Ca	Mg	K	P
<i>Hylocomiosa</i> / dry mineral soil	NS	54	C	4.3±1.9 _o	1.0±0.5↓	4±2↓	1.5±0.7↓
			WA	5±2 _o	1.3±0.6↓	5.2±2.3↓	1.8±0.8↓
<i>Hylocomiosa</i> / dry mineral soil	NS	54	C	6.0±0.6↑	1.33±0.9↓	5.2±0.7↓	1.2±0.2↓
			WA	4.9±0.8 _o	1.36±0.9↓	5.4±0.7↓	1.58±0.09↓
<i>Hylocomiosa</i> / dry mineral soil	NS	50	C	5.1±0.3↑	1.41±0.05↓	6.3±0.4 _o	1.37±0.06↓
			WA	5.9±0.5↑	1.52±0.08 _o	6.0±0.5 _o	1.42±0.07↓
<i>Myrtillosa mel.</i> / drained mineral	NS	53	WA	3.5±0.2 _o	0.99±0.03↓	4.3±0.2↓	1.05±0.04↓
<i>Myrtillosa mel.</i> / drained mineral soil	NS	44	C	6.8±0.4↑	1.7±0.2 _o	6.7±0.7 _o	1.4±0.1↓
			WA	7.2±0.4↑	1.65±0.08 _o	6.7±0.3 _o	1.20±0.08↓
<i>Myrtillosa mel.</i> / drained mineral soil	NS	45	C	4.2±0.5 _o	1.24±0.05↓	7.2±0.4 _o	2.2±0.1 _o
			WA	4.1±0.2 _o	1.28±0.03↓	7.7±0.8 _o	2.1±0.1 _o
<i>Myrtillosa turf. mel.</i> / drained organic soil	NS	48	C	4.3±0.2 _o	1.19±0.05↓	6.4±0.4 _o	1.6±0.1↓
			WA	5.4±0.6↑	1.2±0.1↓	6.6±0.3 _o	1.61±0.09↓
<i>Myrtillosa turf. mel.</i> / drained organic soil	SP	94	C	3.9±0.7↑	1.25±0.05↑	4.8±0.1↓	1.8±0.1↑
			WA	3.9±0.3↑	1.26±0.04↑	5.1±0.2 _o	1.82±0.04↑
<i>Oxalidosa turf. mel.</i> / drained organic soil	NS	54	C	7.9±0.6↑	1.39±0.06↓	2.3±0.3↓	1.33±0.09↓
			WA	8.6±0.7↑	1.38±0.05↓	2.1±0.2↓	1.14±0.03↓
<i>Oxalidosa turf. mel.</i> / drained organic soil	NS	49	C	6.1±0.7↑	1.24±0.02↓	2.4±0.2↓	1.49±0.08↓
			WA	6.9±0.5↑	1.1±0.1↓	2.3±0.2↓	1.2±0.2↓

NS – Norway spruce
SP – Scots pine
C – control plot
WA – wood ash treated plot

_o – optimal concentration of element
↑ – concentration of element exceeds the optimum level
↓ – concentration of element is below the optimum level

In this experimental group, the most pronounced impact of wood ash on the chemistry of current year needles was revealed in elevated concentrations of potassium and phosphorus, if control and fertilized plots were compared. The elevated concentrations of calcium and magnesium were detected in comparatively smaller number of experimental objects. However, there was a statistically significant increase in the content of potassium and phosphorus in some of the Norway spruce and Scots pine stands, while in literature significant increase of potassium has been observed in coniferous stands on mineral soil (Jacobson, 2003).

According to the nutrient values given by Nollendorfs (2008), the calcium level is high in most Norway spruce stands, and magnesium level is determined as optimal in these objects. The chemical composition of current year needles showed diminished concentrations or even deficiency of potassium. It could be explained with antagonism between calcium and potassium (Mandre, 2006). Deficient status of phosphorus was detected in 54-years old Norway spruce stand on drained organic

soil, but in the most part of Norway spruce stands the potassium content was optimal.

The detected nutrient levels in the needles are optimal or even above the optimum level in the trial objects of Scots pine. In comparison with the trial objects of Norway spruce, the concentration of calcium in needles of Scots pine was relatively lower, similarly to the 94-year-old Scots pine experimental objects treated with wood ash (Table 4).

It must be noted that part of the nutrients that were detected in needles, may have been accumulated on needle surface. The needles collected in this research were not washed with distilled water before drying. However, according to the ICP Forest Guidelines on Sampling and Analysis of Needles and Leaves (Rautio *et al.*, 2017), only samples collected from polluted areas or from regions near the sea should be washed. Moreover, the design of this research focuses on estimation of the impact of wood ash treatment by comparing differences of control and treated plots at the individual research object. So the chemical properties were compared for the samples collected from relatively similar conditions, except for the fertilization.

Table 5

Nutrient concentrations in needles from control and combined wood ash and ammonium nitrate fertilized treated plots

Forest type	Tree species	Stand age	Plot	Ca	Mg	K	P
<i>Vacciniosa mel./</i> drained mineral soil	SP	66	C	3.7±0.4↑	1.13±0.08↑	*5.8±0.1o	1.7±0.2↑
			WAN	3.0±0.3o	1.07±0.06↑	*6.6±0.2↑	2.28±0.09↑
<i>Vacciniosa mel./</i> drained mineral soil	SP	65	C	3.4±0.1↑	1.33±0.05↑	5.5±0.2o	2.13±0.06↑
			WAN	3.0±0.2o	1.18±0.07↑	6.1±0.2↑	2.30±0.08↑
<i>Vacciniosa turf. mel./</i> drained organic soil	SP	59	C	2.6±0.2o	1.47±0.08↑	5.7±0.2o	*2.09±0.03↑
			WAN	2.8±0.6o	1.37±0.04↑	5.9±0.3o	*2.28±0.07↑
<i>Myrtillosa mel./</i> drained mineral soil	NS	38	C	7.3±0.5↑	1.72±0.08o	3.4±0.3↓	2.2±0.2o
			WAN	6.1±0.7↑	1.6±0.1o	4.6±0.5↓	2.2±0.1o
<i>Myrtillosa mel./</i> drained mineral soil	NS	36	C	6.6±0.9↑	1.59±0.03o	*4.5±0.6↓	*1.95±0.07
			WAN	7.0±0.7↑	1.52±0.07o	*5.7±0.7↓	*2.3±0.1
<i>Myrtillosa turf. mel./</i> drained organic soil	NS	58	C	7.5±0.4↑	1.76±0.05o	2.5±0.2↓	2.3±0.1o
			WAN	7.6±0.6↑	1.65±0.07o	3.2±0.3↓	2.00±0.07o
<i>Vacciniosa turf. mel./</i> drained organic soil	SP	60	C	3.6±0.3↑	1.31±0.07↑	5.5±0.1o	NV
			WAN	3.3±0.4↑	1.4±0.1↑	6.8±0.9↑	2.2±0.3↑
<i>Oxalidososa turf. mel./</i> drained organic soil	NS	54	C	4.4±0.7o	0.95±0.07↓	1.60±0.07↓	1.30±0.05↓
			WAN	4.7±0.3o	1.05±0.07↓	1.9±0.2↓	1.22±0.07↓

NS – Norway spruce

SP – Scots pine

C – control plot

WAN – wood ash and ammonium nitrate treated plot

o – optimal concentration of element

* – statistically significant differences between control plot and treated plot (p<0.05)

↑ – concentration of element exceeds the optimum level

↓ – concentration of element is below the optimum level

NV – no value

Correlation between chemical parameters of needles and soil

Only statistically significant correlations are summarized in Table 6. Correlations between nutrient concentrations in needles and soil among fertilized

plots were found for P, in particular for those plots on drained mineral soil. These relationships also for Ca at Norway spruce stand and for Mg at Scots pine stand characterizes nutrient availability in these trial objects and accessibility for trees.

Table 6

Significant Spearman rank correlation (p<0.05) between nutrient concentration in needles and soil

Soil	Forest type	Dominant tree species	Stand age	Plot	Ca	Mg	K	P
Wood ash treated objects								
Dry mineral soil	<i>Hylocomiosa</i>	Norway spruce	50	C		-0.84		
Drained mineral soil	<i>Myrtillosa mel.</i>	Norway spruce	53	WA				0.52
	<i>Myrtillosa mel.</i>	Norway spruce	44	C		-0.88		0.88
Wood ash and ammonium nitrate treated objects								
Drained mineral soil	<i>Vacciniosa mel.</i>	Scots pine	65	WAN				0.64
	<i>Vacciniosa mel.</i>	Scots pine	59	WAN		0.88		
	<i>Myrtillosa mel.</i>	Norway spruce	38	WAN				0.69
	<i>Myrtillosa mel.</i>	Norway spruce	36	C	0.88		-0.88	0.88
Drained organic soil	<i>Vacciniosa turf. mel.</i>	Scots pine	60	WAN	-0.74			

C – control plot

WA – wood ash fertilized plot

WA+N – wood ash and ammonium nitrate fertilized plot

For the most part, the calculated correlations between needle and soil properties of the trial plots are positive, although a few negative relationships are found mostly for the control plots. Considering these results, it is planned to analyze nutrient concentrations in soil and litter samples collected after forest soil treatment from both – control and fertilized plots.

Conclusions

1. There were statistically significant differences only in the concentrations of potassium and phosphorus in the samples of needles collected from the forest stands fertilized first with wood ash and next with ammonium nitrate.
2. For the most part, elevated potassium concentrations in needles were detected in comparison to the control plots, and this tendency was observed in all experimental objects of both tree species and all growth conditions. A similar tendency was detected for calcium and to a lesser extent also for magnesium and phosphorus, thereby, indicating the impact of forest soil fertilization with wood ash.
3. For the most part the nutrient content of needles was optimal or more than optimal in the experimental

objects of Scots pine stands, but optimal or even high content was detected mostly for calcium and magnesium in the current year needles collected from Norway spruce stands.

4. No general pattern of nutrient concentration in the needles was detected for forest types, dominant tree species or stand age, except for calcium, which was detected in relatively higher concentrations in Norway spruce stands.
5. We found only few correlations between nutrient content in needles and in soil samples collected before the forest soil fertilization.

Acknowledgements

The study is implemented within the scope of the memorandum between the Joint Stock Company 'Latvia's State Forests' and LSFRI 'Silava' on 'Collaboration in scientific research' from October 11, 2011. The research was conducted within the scope of the Joint Stock Company 'Latvia's State Forests' research project 'Research program on forest fertilization' (2016–2021).

References

- Bardule, A., Lazdina, D., Bardulis, A., & Sarkanabols, T. (2018). Macronutrient leaching in a fertilized juvenile hybrid aspen (*Populus tremula* L. × *P. tremuloides* Michx.) plantation cultivated in an agroforestry system in Latvia. *Hydrology Research*, 49(2), 407–420. DOI: 10.2166/nh.2017.054.
- Bardule, A., Rancane, S., Gutmane, I., Berzins, P., Stesele, V., Lazdina, D., & Bardulis, A. (2013). The effect of fertiliser type on hybrid aspen increment and seed yield of perennial grass cultivated in the agroforestry system. *Agronomy Research*, 11(1), 13–24.
- Cabinet of Ministers of Latvia. (2015). *Regulations Regarding the Identification, Quality Conformity Assessment and Sale of Fertilisers and Substrates. No 506*. Retrieved March 13, 2020, from <https://likumi.lv/ta/en/en/id/276480-regulations-regarding-the-identification-quality-conformity-assessment-and-sale-of-fertilisers-and-substrates>.
- Jacobson, S. (2003). Addition of Stabilized Wood Ashes to Swedish Coniferous Stands on Mineral Soils – Effects on Stem Growth and Needle Nutrient Concentrations. *Silva Fennica*, 37(4), 437–450. DOI: 10.14214/sf.483.
- Jansons, Ā., Matisons, R., Krišāns, O., Džeriņa, B., & Zeps, M. (2016). Effect of initial fertilization on 34-year increment and wood properties of Norway spruce in Latvia. *Silva Fennica*, 50 (1), 1–8. DOI: 10.14214/sf.1346.
- Kaposts, V., & Saceniņš, R. (1981). *Mežaudžu barošanās režīms un to mēslošana (Nutritional regime and fertilization of forest stands)*. Riga: LatZTIZPI. (in Latvian).
- Libiete, Z., Bardule, A., Klavins, I., Kalvite, Z., & Lazdins, A. (2019). Medium-term impact of stump harvesting on general soil parameters in *Hylocomiosa* site type. In annual 25th International scientific conference: Research for Rural Development 2019, 15–17 May 2019 (pp. 58–64).
- Libiete, Z., Bardule, A., Murniece, S., & Lupikis, S. (2017). Impact of clearfelling on dissolved nitrogen content in soil-, ground-, and surface waters: initial results from a study in Latvia. *Agronomy Research*, 15(3), 767–787.
- Mandre, M. (2006). Influence of wood ash on soil chemical composition and biochemical parameters of young Scots pine. *Proc. Estonian Acad. Sci. Biol*, 55(2), 91–107.
- Nollendorfs, V. (2008). *Egļu audžu panākuma un sabrukšanas cēloņu noskaidrošana, to samazināšanas iespējamie pasākumi (Identification of causes of decline and deterioration of spruce stands, possible measures to diminish those causes)*. Salaspils: LSFRI Silava. (in Latvian).
- Okmanis, M., Kalvis, T., & Lazdina, D. (2018). Initial evaluation of impact of evenness of spreading wood ash in forest on additional radial increment. In 17th International Scientific Conference: Engineering for Rural

- Development, 23–25 May, 2018 (pp. 1902–1908). Jelgava, Latvia: Latvia University of Life Sciences and Technologies. DOI: 10.22616/ERDev2018.17.N491.
- Ozolincius, R., Armolaitis, K., Raguotis, A., Varnagiryte, I., & Zenkovaite, J. (2006). Influence of wood ash recycling on chemical and biological condition of forest Arenosols. *Journal of Forest Science*, 52(Special Issue), 79–86. DOI: 10.17221/10164-JFS.
- Ozolincius, R., Buozyte, R., & Varnagiryte-Kabasinskiene, I. (2007). Wood ash and nitrogen influence on ground vegetation cover and chemical composition. *Biomass and Bioenergy*, 31(10), 710–716. DOI: 10.1016/j.biombioe.2007.06.015.
- Pitman, R.M. (2006). Wood ash use in forestry – a review of the environmental impacts. *Forestry*, 79(5), 563–588. DOI: 10.1093/forestry/cpl041.
- Rautio, P., Fürst, A., Stefan, K., Raitio, H., & Bartels, U. (2017). *Part XII: Sampling and Analysis of Needles and Leaves*. In: *UNECE ICP Forests Programme Co-ordinating Centre (ed.): Manual on methods and criteria for harmonized sampling, assessment, monitoring and analysis of the effects of air pollution on forests*. Thünen Institute of Forest Ecosystems, Eberswalde, Germany.
- Saarsalmi, A., & Mälkönen, E. (2001). Forest Fertilization Research in Finland: A Literature Review. *Scandinavian Journal of Forest Research*, 16(6), 514–535. DOI: 10.1080/02827580152699358.
- Vincevica-Gaile, Z., Stankevica, K., Irtiseva, K., Shishkin, A., Obuka, V., Celma, S., & Klavins, M. (2019). Granulation of fly ash and biochar with organic lake sediments – A way to sustainable utilization of waste from bioenergy production. *Biomass and Bioenergy*, 125, 23–33. DOI: 10.1016/j.biombioe.2019.04.004.

COMPOSITION OF EXTRACTS ISOLATED FROM BLACK ALDER BARK BY MICROWAVE ASSISTED WATER EXTRACTION

* **Alexandr Arshanitsa, Jevgenija Ponomarenko, Maris Lauberts, Vilgelmina Jurkjane, Lilija Jashina, Alexandr Semenischev, Jegor Akishin, Galyna Telysheva**

Latvian State Institute of Wood Chemistry, Latvia

*Corresponding author's email: arshanica@edi.lv

Abstract

The composition of extracts isolated from black alder bark by 'green' microwave assisted water extraction in the temperature range of 70–150 °C was studied using the wet chemistry Folin-Ciocalteu method and Py-GC-MS/FID. The composition data were compared with those of the extracts obtained at the same temperature by accelerated solvent extraction (ASE) of bark. It was shown that microwave assisted extraction, compared with ASE, resulted in more significant transition of major cell wall components, including hemicelluloses and phenolics of lignin origination, into the solution. Depending on the microwave assisted extraction regimes, products with different portion of major cell wall components and secondary phenolic metabolites can be isolated that enlarge the possibilities of products valorisation. Thus, a significant promotion of secondary phenolic metabolites' transition into extracts as a result of microwave extraction was observed at 70 °C. At that time the relative portion of carbohydrates in extracts was increased at high temperature extraction, combining dynamic and isothermal microwave heating. Water extraction of black alder bark in a microwave extractor revealed 25–50% lower specific energy consumption and 1.8–2.6 times higher productivity in comparison with the conventional extraction, that is beneficial in view of the upscale and practical application of this innovative biomass processing.

Key words: Bark, extraction, microwave, plant phenols, carbohydrate.

Introduction

By the ecological factors, decreasing the CO₂ emission is the global task that has to be solved by human society in the nearest future. Therefore, different branches of manufacturing within rural and industrial sectors of economy are challenged to find new technologies in order to reduce energy consumption and maximize the valorisation of the renewable raw material for the development of economic sustainability.

The biorefinery concept, which is defined as a range of combined technologies aimed at the waste free transformation of biomass into commodity or specialty chemicals and added value materials, is the fundamental approach for developing new and more sustainable processes (Morais & Bogel-Lukasik, 2013; Rombaut *et al.*, 2014). Wood biomass, renewable in the photosynthetic process, is an ideal feedstock for a wide range of processing since it does not affect food supplies (Tabasso *et al.*, 2015; Popa & Volf, 2018).

In each step of forest biomass conversion, a significant amount of waste is generated. The biggest underexploited lignocellulosic waste is tree bark, the output of which only in Latvia achieves 1 mln. m³ per year (LR Zemkopības Ministrija, 2018). Currently, bark is used mainly for heat production by direct combustion, which does not correspond to its potential. However, due to the presence of secondary metabolites with unique composition, bark can be used for valuable phytochemicals' isolation, although with a small output, but characterized with a high added value.

Alder (*Alnus incana* and *Alnus glutinosa*) is assessed as a biorefinery feed as it is the only native

fast growing large tree with nitrogen fixating and deep phosphorus retrieval symbiosis characteristics in the Northern European region including the Baltic countries and because it has already been proposed for replenishment management of depleted soils in these areas (Thomsen, Ahrenfeld, & Thomsen, 2013) In this context, alder barks have a high potential to be an integral part of biorefinery processes, as they contain valuable monomeric, oligomeric and polymeric compounds, which can be converted into numerous value-added products (Ren *et al.*, 2017).

Based on the above-mentioned, in present work, liquid-solid extraction of black alder bark was studied as a subcomponent of bark biorefinery. Taking into account the main requirements of green chemistry, additives free deionized water was used as a solvent and microwave (MW) assisted heating was used as an alternative of conventional heating methods. The selection of the MW technology for the given study is associated with the fact that MW extraction in many cases was revealed as a more effective method in comparison with not only conventional methods, but also with modern advanced extraction methods, because extraction occurs as a result of changes in the cell structure caused by the electromagnetic irradiation and synergistic combination of two transport phenomena: heat and mass gradients working in the same direction as well (Veggi, Martinez, & Meiriles, 2012).

The aim of the present work was evaluation of the effectiveness of black alder bark water MW-assisted extraction, including that in terms of specific energy consumption and development of the optimal extraction regimes. The data obtained were compared with the results of extraction by the

modern advanced accelerated solid ASE method where convective/conductive heat transfer takes place. For the realization of controlling the MW assisted extraction, a laboratory device of original construction was used. The effect of the extraction temperature and isothermal heating duration on the yield and composition of extracts removed was in focus of the present research. With this aim, Py-GC-MS/FID and wet chemistry procedures, including the measurement of the total polyphenolic content, were used as the main analytical tools.

Materials and Methods

Bark removed by handle debarking of a 27 years' age black alder (*Alnus glutinosa*) tree harvested in Talsu municipality of Latvia was used as an object of investigation. The isolated bark was air dried (~20 °C) up to the water content of 9%, then ground by a Retch 100 knife type mill equipped with a 2.00 mm sieve.

The MW extraction column of original construction consisted of a circular coaxial wave guide with three magnetrons (output MW power – 0.850 kW per each), an extraction chamber (V=1350 cm³), power supply units, a vacuum pump, a cooling section, and a pressure relief valve was used for biomass extraction (Figure 1).

In each experiment, 108.50 g of bark (water content = 9.0%) and 550.00 g of deionized water (T=18–20 °C) were loaded into the extraction chamber. After that the column was assembled and vacuum treatment of the suspension at the residual

pressure of 50 mbar was done during 5 min to ensure the penetration of the solvent inside the substrate. Then, the atmospheric pressure in the chamber was recovered and continual microwave heating of the composition up to the desirable temperature varied in the range of 70–150 °C was performed, followed by the automatically controlled isothermal heating during 5–30 min that was achieved by the on/off action regime of microwave generators. After the exposition of the composition at a given temperature, the pressure inside the closed extraction chamber was removed by turning-on of the relief valve connected to the extraction chamber and the cooling section. After the 5-min exposition, the chamber was removed from the extraction column to be mounted into the screw gearing press to separate solid and liquid fractions. For each chosen temperature magnitude, one experiment was performed without the isothermal heating stage, e.g. a drop in pressure was done immediately after the achievement of the desirable temperature inside the extraction chamber. The liquid fraction enriched with extractives was filtered using Buchner funnel, followed by lyophilic drying. The yield of dry extracts in relation to dry bark was measured by weighing. The powder-like extracts were placed in a plastic box for freezing storage at -17 °C. The specific energy consumption, depending on the temperature value and extraction duration, was measured using a power indicator SENECA S604E-6-MOD. Each experiment was repeated three times and the data were averaged. The variation coefficient of measurement was ≤10%.

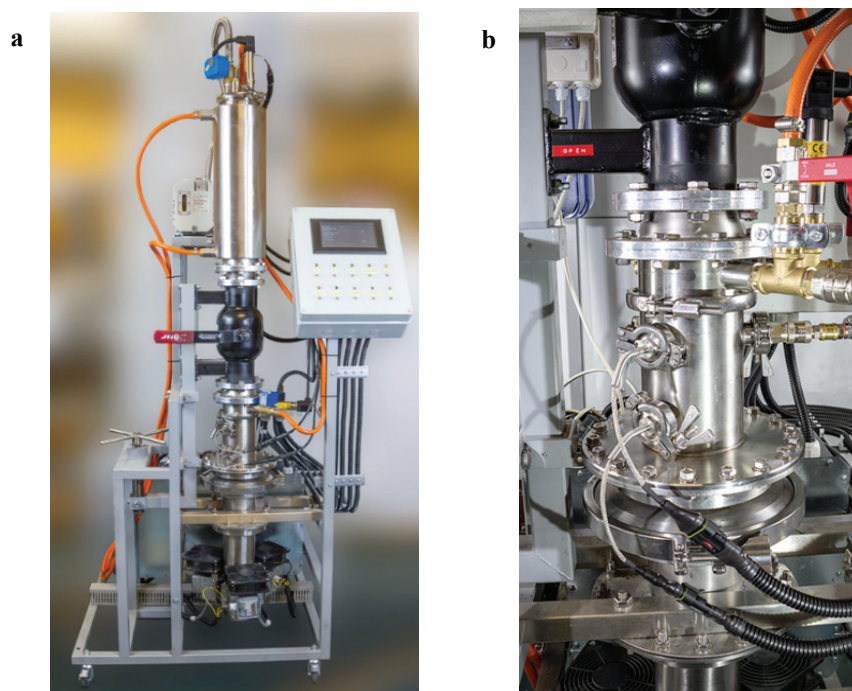


Figure 1. The column for MW assisted water extraction of black alder bark: common assembly view (a), view of extraction chamber (b).

The ASE water extraction of bark was performed using a laboratory scale device DIONEX ASE. About 40.00 g of black alder bark was loaded into the extraction cell, followed by processing consisting of four repeated extraction cycles with a fresh portion of the solvent at temperatures varied in the range of 70–150 °C during 5 min per each cycle. Earlier, this regime was recognized as the optimal one in terms of the extract yield (Lauberts, 2018). For each experiment, 300±20 mL of the extractives' rich solvent were obtained. The yield of the lyophilic dried extract was measured by weighing. Each experiment was repeated three times and the data were averaged. Variation coefficient of measurement was ≤ 10%.

The total phenolic content (TPC) of extracts was determined by wet chemistry methods using Folin-Ciocalteu reagent. The optical intensity of the resulted coloured complex at 765 nm was measured against gallic acid solution as a blank (Singleton, Orthofer, & Lamuela-Raventos, 1999). The total phenolic contents were expressed as grams (g) of gallic equivalents (GAE) per gram of a dried sample of the extract.

Py-GC/MS/FID analysis was performed using a Frontier Lab (Fukushima, Japan) Micro Double-shot Pyrolyzer Py-3030D (pyrolysis temperature 500 °C, heating rate 600 °C s⁻¹) directly coupled with the Shimadzu GC/MS/FID-QP ULTRA 2010 apparatus (Japan) equipped with a capillary column RTX-1701 (Restec, Metairie, Louisiana, USA) and a 60 m × 0.25 mm × 0.25 mm film (injector temperature of 250 °C, ion source with EI of 70 eV, MS scan range m/z of 15–350, carrier gas helium at the flow rate of 1 mL min⁻¹ and a split ratio of 1:30). The mass of the sample probe (residual moisture content < 1%) was 1.00–2.00 mg. The oven program was as follows: 1 min isothermal at 60 °C, followed by 6 °C min⁻¹ to 270 °C, and the final hold at 270 °C for 10 min. The mass spectrometer was operated in electron impact mode using 70 eV electron energy. The identification of the individual compounds was performed based on GC/MS chromatography using Library MS NIST 11 and NIST 11 s, whereas the relative area of the peak of individual compounds was calculated using Shimadzu software based on GC/FID data. The summed molar areas of the relevant peaks were normalized to 100%, and the data for four repetitive pyrolysis experiments were averaged. CV of measurements was ≤ 8%.

Results and Discussion

Bark refers to lignocellulosic biomass, which is mainly composed of carbohydrate polymers: cellulose, hemicellulose and aromatic polymer lignin. It also contains extractives and ash. The chemical composition of bark differs depending on the tree species. Bark differs chemically from stem wood with an overall higher proportion of ash and extractives

(Marmol *et al.*, 2019; Leite & Pereira, 2017; Neiva *et al.*, 2018). Extractives are composed of a wide array of individual hydrophobic and hydrophilic compounds ranging from terpenoids and steroids, fats, and waxes to phenolic compounds including stilbenes, tannins and flavonoids. The most characteristic feature of the *Alnus* genus is the occurrence of large quantities of diarylheptanoids and their glycosides in different morphological parts of the tree. It is known, that many of valuable phenolic compounds are present not only within cytosolic spaces but are also bound within plant cellular walls. Plant cell walls consist of a series of complex structural polysaccharides such as cellulose, hemicellulose and lignin (an aromatic polymer) and even proteins. This structure is what confers to the cells stability and resistance to the extraction of the intracellular components (Gligor *et al.*, 2019). Therefore, one of the objectives of this study was to evaluate the influence of the MW-assisted water extraction in different conditions not only on secondary metabolites' isolation but also on the transition of the cell wall main components into solution. The advanced ASE extraction method was used as the reference. The yield of the water extracts obtained from black alder bark by ASE extraction varied from 19.2% (on DM) at 70 °C up to 28.9% at 150 °C. The yield of the water extracts obtained by MW-assisted extraction increased with increasing temperature and varied from 15.4% (on DM) to 26.4% depending on the extraction conditions. In this case, the effect of the temperature magnitude on the yield of extractives was more pronounced in comparison with that of the extraction duration.

The composition of black alder bark extracts was studied, using the Py-GC-MS/FID method well known as analytical pyrolysis. This method is widely used for the characterization of the chemical composition of lignocellulosic biomass by the determination of pyrolysis products referring to the definite biomass components (González-Vila, 1997). The application of AP for the studies of the composition of the obtained extracts allowed simultaneous evaluation of the transition to the extracts of all components of bark biomass, including high molecular weight cell wall components (carbohydrates and lignin) and their derivatives, lipophilic and hydrophilic extractives. The products of carbohydrates' thermal degradation in conditions of AP consist of aliphatic acids and esters, aliphatic alcohols, aliphatic aldehydes and ketones, furan and pyran derivatives, cyclopentane derivatives and sugars. The lignin degradation products consist of methoxylated phenols, guaiacyl (G-) and syringyl (S-) derivatives (Figure 2).

The method is mostly used for the characterization of the main biomass components *in situ*; however, there are some studies concerning the application of

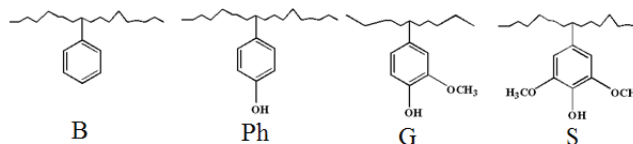


Figure 2. Classification of the aromatic pyrolysis products.

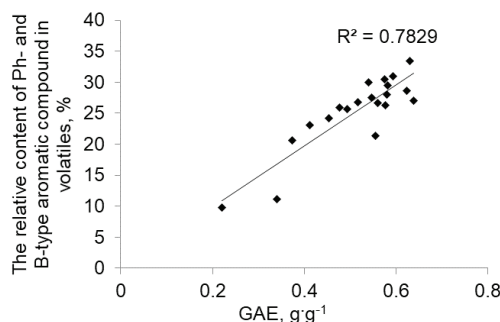


Figure 3. Correlation between the total phenols (GAE g·g⁻¹) content in extracts isolated from black alder bark by both extraction methods and relative content of non-methoxylated phenols in volatiles, determined by Py-GC-MS/FID.

Py-GC-MS/FID for the characterization of extractives isolated from plant substrates (Ohra-aho, 2017). As the lignocellulosic material under study contains lignin, which consists only of G- and S-units, the normalized area of peaks in Py-GC-MS/FID chromatograms for products, related to B- and Ph-type phenols, reflects the content of phenolic extractives in the samples of isolated extracts.

This assumption is confirmed by the strong positive correlation between the content of total phenols, determined as GAE g·g⁻¹ of the extract and the relative content of non-methoxylated aromatic volatiles in pyrolysis products (Figure 3).

Other significant groups of compounds detected in the AP volatiles are degradation products of lipophilic and N-containing compounds present in extractives.

To get information about the extracts' and parent biomass' compositions, areas of pyrolytic chromatograms peaks, typical for carbohydrates, lignin, lipophilic and hydrophilic extractives degradation products and N-containing products, were summed up and normalized to 100%. According to the obtained data, the volatiles of the parent black alder bark consist of 72.6% of carbohydrates derived compounds; 20.1% of lignin derived compounds (G- and S-type phenols); 5.5% of hydrophilic extractives derived compounds (Ph- and B-type phenols); 1.6% of lipophilic extractives derived compound and 0.2% of N-containing compounds. Carbohydrates are also the main constituents of all the obtained water extracts (Figure 4). The carbohydrate content tends to increase with increasing ASE temperature. The composition of extracts, obtained by MW-assisted extraction

without isothermal heating at the corresponding temperature, is close to that of water extracts, obtained by ASE extraction (isothermal heating time = 20 min). However, the MW assisted extraction revealed the specific energy consumption lower by 25–52% and a higher productivity of the process, which was defined as the average yield of extracts on the DM of bark per time unit of processing.

The productivity of MW assisted extraction varied in the range of 1.3–1.1% min⁻¹ vs 0.6–0.5% min⁻¹ for ASE processing. The relative content of carbohydrates derived products in volatiles of MW extracts was slightly dependent on the temperature magnitude when only short term dynamic MW heating took place and was about 60%. A similar dependence was observed for ASE processing although the long term (20 min) heating was performed in this case (Figure 4). The ratio of carbohydrates derived products to lignin derived products is 4.4–5.8 for extracts, obtained by ASE extraction and 5.2–5.7 for extracts, obtained by MW-assisted extraction. This ratio for parent black alder bark is 3.6. The composition of extracts, obtained by MW-assisted extraction including 15 and 30 min of isothermal heating at the corresponding temperature (70–110 °C), is close to that of the above-described extracts; however, it differs at 130 °C and strongly differs at 150 °C extraction temperatures. In contrast to the extracts obtained by ASE extraction, the extracts obtained by MW-assisted extraction have a significantly higher content of carbohydrates derived volatiles (it reaches 78% at 150 °C). This indicates the promoting effect of MW irradiation on the plant cell degradation. It was proven by the fact that the

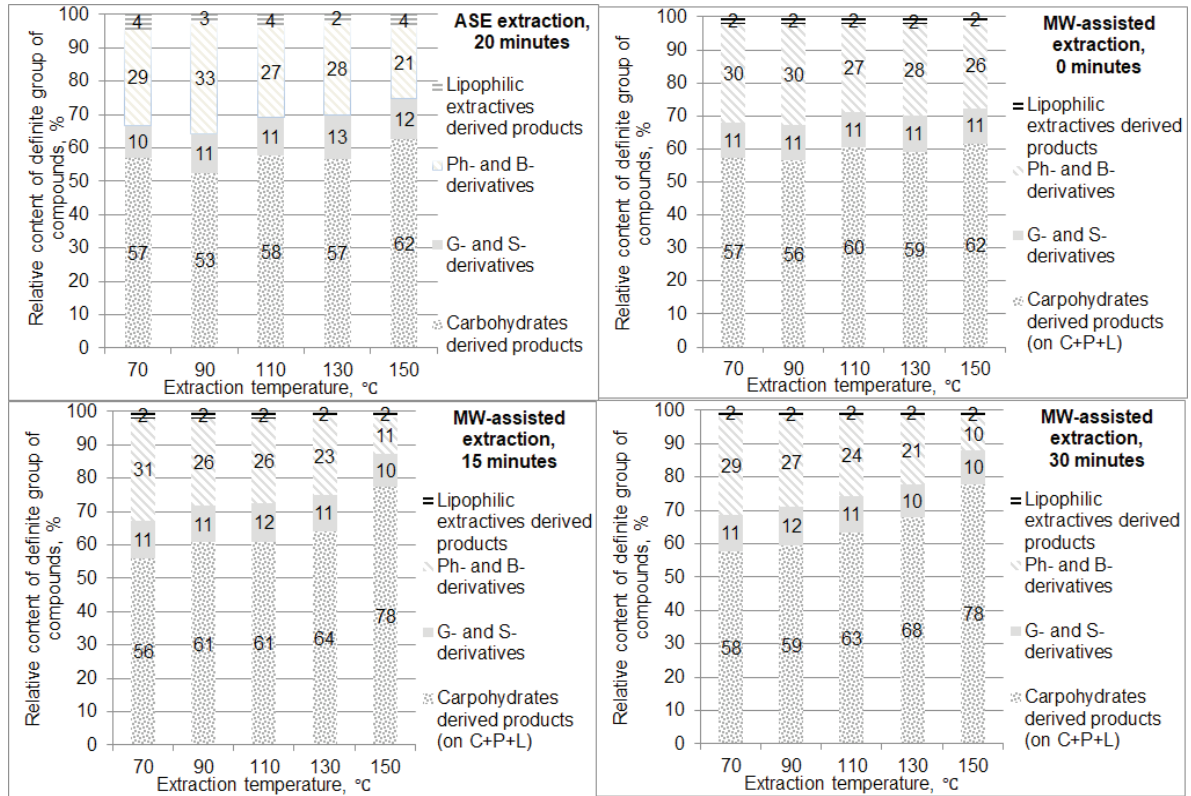


Figure 4. Composition of black alder bark water extracts, depending on extraction methods and process conditions.

extracts obtained by MW-assisted extraction have a higher portion of lignin derived methylated phenols in aromatic volatiles in comparison to the extracts obtained by ASE extraction. There is a strong positive correlation between the carbohydrates derived products' content and the lignin-derived products' content, pointing to cell wall degradation (Figure 5).

As extracts, obtained by MW-assisted extraction, have a higher relative content of pyrolysis products

related to cell wall components, it can be concluded that the MW-assisted extraction much more affects the degradation of the cell wall in comparison to the ASE extraction. The especially strong degradation of the wall cell was observed for extracts, obtained by the MW-assisted extraction at 150 °C at 15 min and 30 min of extraction (Figure 5).

Phenolic extractives are important components of the obtained water extracts (Figure 4). However, it is

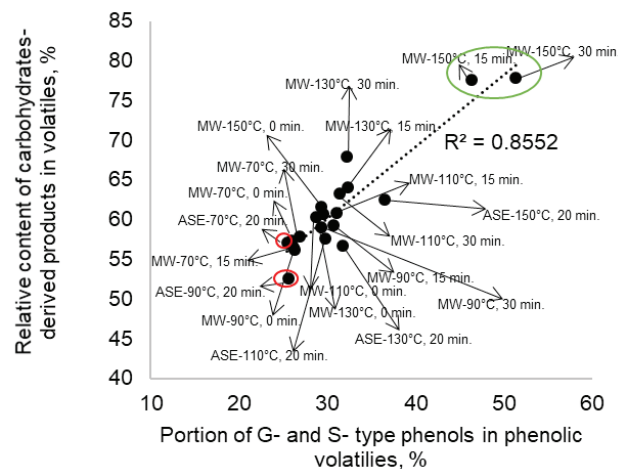


Figure 5. Correlation between the portion of lignin-derived products in aromatic volatiles and relative content of carbohydrates derived products in total pyrolysis volatiles.

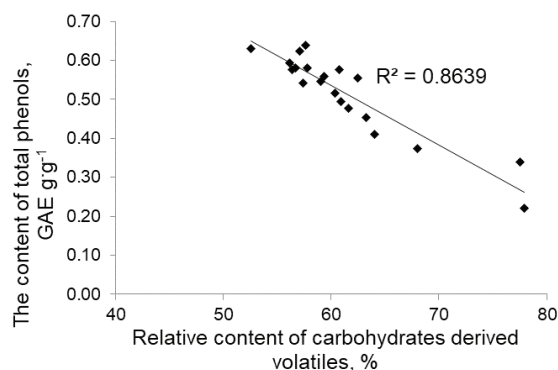


Figure 6. Correlation between the relative content of carbohydrates derived products in volatiles of extracts isolated by both extraction methods and content of total phenols (GAE g·g⁻¹) in them.

Table 1

Transition of the phenolic compounds (hydrophilic extractives) to extracts, depending on extraction conditions

Extraction regime	Total phenols, GAE g·g ⁻¹	The ratio of hydrophilic (phenolic) extractives derived pyrolysis products to lipophilic extractives derived products
ASE-70 °C, 20 min	0.62	6.4
MW-70 °C, 0 min	0.54	14.6
MW-70 °C, 15 min	0.59	15.7
MW-70 °C, 30 min	0.58	15.4
ASE-90 °C, 20 min	0.63	13.1
MW-90 °C, 0 min	0.58	13.5
MW-90 °C, 15 min	0.58	13.2
MW-90 °C, 30 min	0.56	12.6
ASE-110 °C, 20 min	0.64	7.0
MW-110 °C, 0 min	0.52	12.9
MW-110 °C, 15 min	0.49	13.1
MW-110 °C, 30 min	0.45	16.0
ASE-130 °C, 20 min	0.58	12.6
MW-130 °C, 0 min	0.55	13.8
MW-130 °C, 15 min	0.41	12.8
MW-130 °C, 30 min	0.37	12.7
ASE-150 °C, 20 min	0.55	5.6
MW-150 °C, 0 min	0.48	14.7
MW-150 °C, 15 min	0.34	6.7
MW-150 °C, 30 min	0.22	4.6
Black alder bark		3.6

impossible to evaluate the effect of the MW-assisted degradation of the cell wall on the transition of the phenolic compounds to the extracts, using the content of total phenols, GAE g·g⁻¹, due to the dilution effect of carbohydrates (Figure 6).

The transition of the phenolic extractives to the extracts can be evaluated using the ratio of (Ph+B) aromatic volatiles to lipophilic extractives derived

products (Table 1). This approach is based on the well-known data of the poor solubility of lipophilic extractives in water even at a high extraction temperature. As a result, this ratio for parent black alder bark enriched with a lipophilic compound is 3.6 and varies from 5.6 to 16.0 for the obtained water extracts. It can be noted that, at 70 °C, the extracts obtained by microwave-assisted extraction have significantly

higher ratios of phenolic extractives derived volatiles to lipophilic extractives derived volatiles. The above mentioned fact points to a higher transition of the phenolic extractive compound from the bark to the extracts under the MW-treatment (Table 1).

Exemplified by black alder bark, the results obtained indicate that microwave assisted extraction revealed itself as a flexible and low energy expensive method of tree bark processing that allows controlling the composition of the isolated extracts. It can be explained by the specific effect of MW irradiation, promoting the process of cell wall degradation and the high solubility of secondary metabolites in the presence of two attended factors: temperature and polar solvent. For complete clarification, this 'non-thermal effect' of microwave needs the further comprehensive research. The magnitude of the microwave power introduced into the substrate and the duration of microwave irradiation are tools, the variation of which allows controlling the transition of secondary metabolites and the main cell wall components to the extracts.

Conclusions

1. It has been shown that, at a given temperature, the effect of water microwave assisted extraction on the degradation of black alder bark cell wall is more pronounced in comparison to that achieved by ASE water extraction.

References

- Popa, V., & Volf, I. (2018). *Biomass as Renewable Raw Material to Obtain Bioproducts of High-tech Value*. Elsevier. DOI: 10.1016/C2015-0-05810-5.
- Gligor, O., Mocan, A., Moldovan, C., Locatelli, M., Crian, G., & Ferreira, I.C. (2019). Enzyme-assisted extractions of polyphenols – a comprehensive review, *Trends in Food Science & Technology*, DOI: 10.1016/j.tifs.2019.03.029.
- González-Vila, F.J., Gutiérrez, A., Martín, F., & Verdejo, T. (1997). Application of analytical pyrolysis to the characterization of Eucalyptus extractives and pitch deposits from a pulp mill. *Journal of Analytical and Applied Pyrolysis*, 40–41, 501–510. DOI: 10.1016/S0165-2370(97)00018-1.
- LR Zemkopības ministrija. (LR ministry of agriculture). (2018). Meža nozare skaitļos un faktos. (Latvian forest sector in facts and figures). Retrieved February 16, 2020, from <https://www.zm.gov.lv/mezi/statiskas-lapas/nozares-informacija/buklets-meza-nozare-skaitlos-un-faktos-?nid=1106#jump>. (in Latvian).
- Lauberts, M. (2018). Isolation of polyphenols from different plant biomass processing residues applied environmentally friendly extraction methods and comprehensive characterization of the products obtained. Summary of Doctoral Thesis, Latvian University, Riga, p. 31.
- Leite, C., & Pereira, H. (2017). Cork-Containing Barks—A Review. *Front. Mater.* 3:63. DOI: 10.3389/fmats.2016.00063.
- Marmol, I., Quero, J., Jiménez-Moreno, N., Rodríguez-Yoldi, M.J., & Ancín-Azpilicueta, C. (2019). A systematic review of the potential uses of pine bark in food industry and health care. *Trends in Food Science & Technology* 88, 558–566. DOI: 10.1016/j.tifs.2018.07.007.
- Morais, A., & Bogel-Lukasik, R. (2013). Green chemistry and the biorefinery concept. *Sust. Chem. Proc* 1:18. DOI: 10.1186/2043-7129-1-18.
- Neiva, D.M., Araújo, S., Gominho, J., de Cássia Carneiro, A., & Pereira, H. (2018). Potential of Eucalyptus globulus industrial bark as a biorefinery feedstock: Chemical and fuel characterization. *Industrial Crops & Products* 123, 262–270. DOI: 10.1016/j.indcrop.2018.06.070.
- Ohra-aho, T. (2017). Characterization of lignocellulose components by analytical pyrolysis gas chromatography mass spectrometry: Dissertation. Espoo: Aalto University

2. The combination of dynamic and isothermal heating regimes at the high temperature MW assisted extraction leads to a dramatic increase in the content of hemicellulose and phenolics of lignin origination in extracts.
3. In comparison with conventional ASE extraction, the MW treatment is more promoting the transition of secondary phenolic metabolites from the plant cell into extracts. The effect is most marketable at 70 °C.
4. Depending on the MW extraction regimes, a different portion of secondary metabolites and major biomass components in extracts can be achieved. This enlarges the possibility of bark extracts valorisation.
5. Water extraction of black alder bark in a MW extractor revealed by 25–50% lower specific energy consumption and 1.8–2.6 times higher productivity in comparison with conventional ASE.

Acknowledgements

The project ERAF No. 1.1.1.1/18/A/182: 'Innovative green extraction process, using water, with elaboration of microwave hybrid reactor and mechano-chemical biomass pre-treatment, creating a new biorefinery cluster oriented to phytochemicals and biomaterials production from underexploited tree biomass' is gratefully acknowledged.

- Ren, X., He, T., Chang, Y., Zhao Y., Chen, X., Bai, S., Wang, L., Shen, M., & She, G. (2017). Review. The Genus *Alnus*, A Comprehensive Outline of Its Chemical Constituents and Biological Activities. *Molecules*. (22), 1383. DOI: 10.3390/molecules22081383.
- Rombaut, N., Tixier, A., Bily, A., & Chemat, F. (2014). Green extraction process of natural products as tools for biorefinery. *Biofuels, Bioprod. & Bioref.* 8 (4), DOI: 10.1002/bbb.1486.
- Singleton, V.L., Orthofer, R., & Lamuela-Raventos, R.M. (1999). Analysis of total phenols and other oxidation substrates and antioxidants by means of folin-ciocalteu reagent. *Methods Enzymol.* 299, 152–178. DOI: 10.1016/S0076-6879(99)99017-1.
- Tabasso, S., Carnraglio, D., Calcio Gaudino, E., & Gravotto, G. (2015). Microwave, ultrasound, and ball mill procedures for bio-waste valorisation. *Green Chem.* 17, 684–693. DOI: 10.1039/C4GC01545B.
- Thomsen, T.P., Ahrenfeld, J., & Thomsen, S.T. (2013). Assessment of a novel alder biorefinery concept to meet demands of economic feasibility, energy production and long term environmental sustainability. *Biomass and Bioenergy.* (53), 81–94. DOI: 10.1016/j.biombioe.2013.02.022.
- Veggi, P.C., Martinez, J., & Meiriles, M.A. (2012). Fundamental of Microwave extraction. In: Chemat, F., Cravotto, G. (Ed.) *Microwave assisted Extraction for Bioactive Compounds: Theory and Practice*, Springer Science & Business Media, 15–50.

PYROLYSIS AND ACID HYDROLYSIS OF LIGNOCELLULOSIC BIOMASS AS A TOOL FOR MONOSACCHARIDE OBTAINING

*Daniela Godina^{1,2}, Ralfs Pomilovskis¹, Nadezda Iljina^{1,2}, Kristine Meile¹, Aivars Zhurins¹

¹Latvian State Institute of Wood Chemistry, Latvia

²University of Latvia, Latvia

*Corresponding author's email: danielagodina393@gmail.com

Abstract

Due to the ever increasing demand for energy resources, more and more attention is being paid to renewable energy resources. One such potential resource is lignocellulosic biomass that can be treated to acquire a carbohydrate rich substrate for further use in producing biofuels such as bioethanol or biobutanol. In this study, birch (*Betula pendula*) chips were used in fast pyrolysis to acquire bio-oil. This bio-oil was further hydrolyzed in pressurized reactor Parr 4554 to produce a carbohydrate rich feedstock. Hydrolysis conditions were optimized. Several conditions - three different temperatures (111, 121, 131 °C) and four different sulfuric acid concentrations (0.05, 0.1, 0.2, 0.5 M) were tested. The optimal conditions were 121 °C with 0.2 M sulfuric acid as a catalyst that allowed to acquire a solution with the total glucose concentration being 6.6% that can be further used as a feedstock for biofuel acquiring.

Key words: acid hydrolysis, lignocellulose, biomass, bio-oil, levoglucosan, glucose.

Introduction

Nowadays, more and more attention is being paid to efficient use of feedstock of biological origin, to produce a wide range of products, from bulk chemicals to highly specialized refined building blocks, in integrated biorefinery concept (Huber, Iborra, & Corma, 2006; Mohan, Pittman, & Steele, 2006). Due to its relatively low cost, wide availability and renewability, lignocellulosic biomass is being extensively studied as a feedstock for production of various platform chemicals as well as energetic resource production (Isikgor & Becer, 2015). In Latvia, one of the most promising lignocellulosic biomass sources is the forestry industry that in addition to targeted products also produces a significant amount of wastage in the form of sawdust, chips, bark, etc. (LR Zemkopības Ministrija, 2018).

Lignocellulosic biomass is mostly composed of three different polymeric compounds. The first is lignin which is a complex macro-molecule mostly made up of different phenyl propane units (p-coumaryl alcohol, coniferyl alcohol, and sinapyl alcohol) (Schuler *et al.*, 2019). Hemicellulose is an amorphous carbohydrate composed of various hexoses and pentoses, mostly glucose, galactose, mannose, arabinose and xylose (Bennett, Helle, & Duff, 2009). Cellulose is composed of glucose sub-units making long ordered fibers with high crystallinity (Ragauskas *et al.*, 2006).

To convert lignocellulosic biomass into fuel, the first step inevitably must be the deconstruction of the solid lignocellulosic material into smaller intermediates that can be further used as building blocks for fuels and chemicals (Huber *et al.*, 2005; Aden *et al.*, 2002; Mohan, Pittman, & Steele, 2006). There are two main pathways for degradation of lignocellulosic biomass. The first is hydrolysis using either acids or enzymes (Mosier *et al.*, 2005). The second is thermal treatment, most commonly it being fast pyrolysis (Lian *et al.*, 2010; Mettler *et al.*, 2012; Czernik & Bridgwater, 2004; Helle *et al.*, 2007). Fast pyrolysis is one of the most interesting pathways for lignocellulosic biomass processing (Sipilä *et al.*, 1998; Oasmaa & Czernik, 1999). It allows to obtain bio-oil which is a complex mixture of various industry-significant chemicals like furfural, 5-hydroxymethylfurfural, various acids, monomeric carbohydrates, anhydro-sugars as well as bigger carbohydrate fragments and phenolic glucosides (Bridgwater, 1999). One important product of fast pyrolysis is levoglucosan (LG) which can easily be obtained and separated from the fast pyrolysis liquor as described previously by us (Meile & Zhurins, 2016).

Since levoglucosan is an anhydrosugar, it can be quite easily hydrolyzed using acidic medium (Figure 1) (Bennett, Helle, & Duff, 2009). Levoglucosan hydrolysis is a first-rate reaction

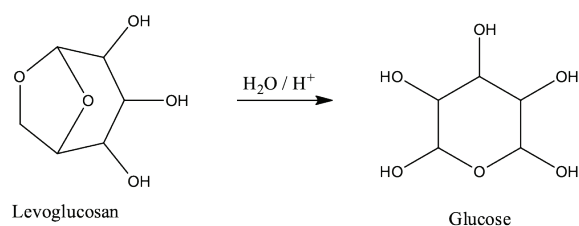


Figure 1. Levoglucosan acid hydrolysis scheme.

since in water medium water concentration remains constant and the reaction rate is dependent only of the levoglucosan concentration (Helle *et al.*, 2007). Also, this acquired bio-oil contains various phenyl glucoside type compounds that can also be hydrolyzed to release free glucose into solution. By combining fast pyrolysis and acid hydrolysis of lignocellulosic biomass it is possible to obtain a solution with a high concentration of monosaccharides that can be further used as a feedstock for production of biofuels, either bioethanol or biobutanol. In this work novel approach, incorporating both fast pyrolysis and acid hydrolysis, is being tested to produce carbohydrate rich feedstock, from lignocellulosic biomass, suitable for application of bio-fuel obtaining. The aim of this work was to obtain feedstock with a high concentration of monosaccharides that can be used as a feedstock for bio-fuel obtaining.

Materials and Methods

Materials and chemicals

Levoglucosan (99%), glucose (99%) and sulfuric acid (95–97%) were purchased from Merck and used without further purification. For HPLC analysis Millipore deionized water was used. All samples were filtered through Kinesis nylon syringe filters (0.22 μm) before HPLC analysis.

Samples

The condensable pyrolysis products were obtained at LSIWC. Birch (*Betula pendula*) chips were treated with diluted sulfuric acid (2% of oven dry wood mass) and washed with deionized water. The obtained lignocellulose was ground to particle size < 2 mm. The lignocellulose was pyrolyzed in a superheated steam (380–420 °C) flow in an entrained flow thermoreactor, after which char was separated in a cyclone, but the liquid products in a condenser.

Pyrolysis liquid sample acid hydrolysis

Anhydro and oligomeric sugars in the fast pyrolysis bio-oil were hydrolyzed in pressurized reactor Parr 4554 with H_2SO_4 at 3 different temperatures (111; 121; 131 °C) and 4 different acid concentrations (0.05, 0.1, 0.2, 0.5 M). For each acid hydrolysis was conducted one parallel experiment. First sample was collected when the temperature in the reactor reached 100 °C, then next sample was collected when set temperature was reached and further with interval of 5 minutes between samples. In total 9 samples were collected per reaction. Since the time to reach the set temperature is different, the total reaction time is different as well for each hydrolysis temperature.

Theoretical glucose content was calculated by Eq. 1.

$$W_{GLC,calc} = W_{GLC,0} + \frac{M_{GLC}}{M_{LG}} \quad (1)$$

HPLC analysis

Qualitative and quantitative measurements of C5 and C6 sugars were done using High Performance Liquid Chromatography Equipment with Column Thermostat, quaternary gradient pump with mobile phase degasification and refractive Index Detector (RI) (ECOM, Czech Republic). For the separation of LG and glucose HPLC Sugar SP0810 column (7 μm , 8 mm x 300 mm) (Shodex, Japan) was used. The column temperature was 80 °C and the mobile phase was Millipore deionized water (Direct – Q 3UV 18.2 $\text{M}\Omega\cdot\text{cm}^{-1}$ 25 °C) with flow rate 0.5 $\text{mL}\cdot\text{min}^{-1}$. Injection volume was 20 μL . Refractive index detector cell temperature was 55 °C.

Hydrolyzed pyrolysis liquid samples were neutralized with barium carbonate for 24 h, then diluted with deionized water and filtered through Kinesis nylon syringe filters (0.22 μm) before analysis.

Partial validation was performed in accordance to Eurachem method validation guidelines (Magnusson & Örnemark, 2014). Tests were done to evaluate the repeatability and trueness of the optimal HPLC method with the Sugar SP0810 column. Repeatability was characterised by the relative standard deviation of six sample solution replicates. Trueness was characterised by the recovery of LG and glucose standard in hydrolyzed pyrolysis liquid samples spiked with 1.0 and 2.0 $\text{mg}\cdot\text{mL}^{-1}$ of LG and glucose. Limit of detection (LOD) and limit of quantification (LOQ) was calculated based on the standard deviation (SD) of four standard solution measurements by Eq.2. and 3, respectively.

$$LOD = \frac{3.3 \times SD}{slope} \quad (2)$$

$$LOQ = \frac{10 \times SD}{slope} \quad (3)$$

Wet chemistry methods of analysis

C6 total sugar content determination with iodometric titration.

To 0.1 g of the sample 0.2 mL of 15% sulfuric acid and 1 mL of 0.2 M sodium periodate solution was added. These samples were heated at 40 °C for 4.5 hours. After that 5 mL of 10% ammonium molybdate was added. After 15 min 1 mL of acetic acid and 1 mL 10% potassium iodide was added. After 15 min the solution was titrated with 0.1 M sodium thiosulfate in the presence of starch as an indicator.

Total aldehyde content determination.

To 2 mL of the sample 5 mL of 10% hydroxylamine solution was added. After 2.5 hours 20 mL of 2-propanol was added, and samples were titrated with 0.1 M KOH solution.

Sulfuric acid determination.

To 1 mL of the sample ~ 20 mL of deionized water was added, and the sample was titrated with 0.1 M KOH solution.

Total solid residue determination.

About 15 mL of the sample was weighted, and the sample was heated at 103 °C until constant mass was reached. The result was determined as the mass difference.

Results and Discussion

HPLC-RI analysis of hydrolyzed pyrolysis liquid samples

To determine levoglucosan and glucose concentration changes in the pyrolysis liquid sample during acid hydrolysis process, an HPLC-RI method was developed using *Shodex Sugar SP0810* column as well as partially validated. Repeatability expressed as relative standard deviation for LG was 9% but for glucose was 5%. Trueness was evaluated at two different levels done in triplicate. When the sample was spiked with 1.0 mg·mL⁻¹ of LG and glucose, the recovery of LG was 103.5% with standard deviation of 1.5%, but for glucose 94.9% with standard deviation of 1.5%, respectively. When the sample was spiked with 2.0 mg·mL⁻¹ of LG and glucose, the recovery of LG was 91% with standard deviation of 1%, but for glucose 93.1% with standard deviation of

1.2%. Linearity was tested within the range from 0.2 to 15.0 mg·mL⁻¹.

The calculated LOD for levoglucosan was 0.07 mg·mL⁻¹ and LOQ was 0.2 mg·mL⁻¹ but for glucose LOD was 0.04 mg·mL⁻¹ and LOQ – 0.11 mg·mL⁻¹.

Parameter optimization of pyrolysis liquid sample acid hydrolysis

Acid hydrolysis optimized parameters for pyrolysis liquid sample, were reaction temperature and the used sulfuric acid concentration.

Temperature optimization for acid hydrolysis.

Initially three different temperatures were tested (111, 121 and 131 °C), but the concentration of sulfuric acid catalyst in solution was 0.2 M. Wet chemistry methods of analysis of completely hydrolyzed samples shows (Table 1) that, when performing hydrolysis with increase of temperature, small increase of total hexose content can be observed that can be explained with hydrolysis of phenyl-glucoside type compounds. Aldehydes in solution with increased temperature undergoes condensation reactions leading to decrease in total aldehyde content.

According to the HPLC-RI data (Figure 2), the reaction rate of levoglucosan hydrolysis increases with the increase of temperature, with the highest rate at 131 °C. At 111 °C hydrolysis rate of levoglucosan was 0.05 %·min⁻¹, at 121 °C it was 0.09%·min⁻¹ but at 131 °C – 0.16%·min⁻¹. When comparing LG

Table 1

Characteristic parameters of hydrolyzed pyrolysis liquid sample at different hydrolysis temperatures (sulfuric acid concentration – 0.2 M)

Hydrolysis temperature, °C	Total hexoses, %	Total solids, %	Aldehydes, %	Sulfuric acid, %
- (initial sample)	3.7	7.8	5.5	0.8
111	6.6	7.4	5.3	2.4
121	6.8	7.3	5.2	2.3
131	7.0	7.3	5.0	2.5

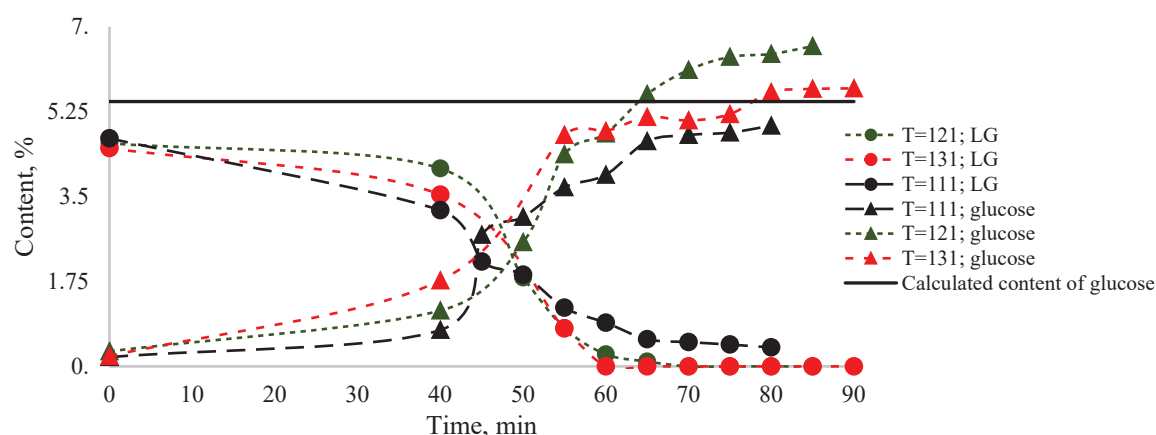


Figure 2. Levoglucosan and glucose content (%) change in time during acid hydrolysis at different temperatures.

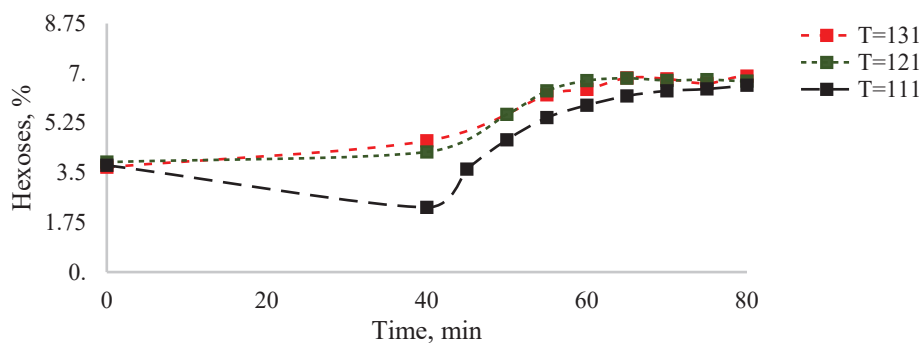


Figure 3. Total hexoses content (%) change in time during acid hydrolysis at different temperatures.

content in relation to time, it is notable that at 111 °C levoglucosan does not hydrolyse fully and reaches equilibrium at 0.4%, but at both temperatures – 121 °C and 131 °C – after 60 minutes levoglucosan is fully hydrolyzed. After LG is fully hydrolysed, the glucose content continues to slowly increase. This can be observed both from HPLC results (Figure 2) and iodometric titration results (Figure 3). When comparing obtained results with calculated glucose content in solution taking into account starting concentrations of LG and glucose, it is apparent that obtained glucose concentration in solution exceeds calculated concentration. This indicates that in addition to LG there are other glucose containing compounds in solution that are being hydrolyzed. These are most likely various phenolic glucosides formed in fast pyrolysis process.

It must be said that although iodometric titration is a fast and widely used method for carbohydrate content determination, it can tend to overestimate results especially if there are reducing compounds present in the sample. Also, this method has bigger uncertainty which can make noticing small differences between samples impossible.

This allows to conclude that in the solution there are glucose containing compounds such as oligomeric carbohydrates or phenolic glucosides that are harder to hydrolyse than LG.

Taking into account these results, for the influence of catalyst content on hydrolysis process, two temperatures were tested – 121 and 131 °C.

Hydrolysis of LG in water solution is a first-rate reaction and is dependent only on the concentration of LG, since the concentration of water remains unchanged for the duration of the reaction. When calculating the rate constants of levoglucosan hydrolysis using 0.2 M H₂SO₄ as catalyst, it was determined to be highly dependent on temperature increasing from 0.053 min⁻¹ at 111 °C to 0.197 min⁻¹ at 121 °C. It was unable to determine the rate constant at 131 °C since the reaction starts, and levoglucosan is partially hydrolyzed, before the temperature is reached.

Acid hydrolysis concentration optimization.

There are quite minor differences in the total hexose content with increased catalyst amount at 121 °C, but by increasing catalyst content from 0.05 M to 0.5 M there is a very prominent increase in the aldehyde concentration (Table 2). This aspect is noteworthy for further study, as increased aldehyde concentration can inhibit the rate at which biofuel is produced.

When comparing HPLC-RI obtained results at 121 °C, the highest amount of glucose in solution was reached by using 0.2 M of sulfuric acid as catalyst (Figure 4). Increase of catalyst load to 0.5 M decreases the time in which the maximum glucose concentration is reached but does not further increase the glucose content.

When considering iodometric titration results content of total hexoses at the end of hydrolysis is practically the same between all concentrations of catalyst due to this method's limitation as described

Table 2
Characteristic parameters of completely hydrolyzed pyrolysis liquid sample using different sulfuric acid concentrations at 121 °C

Sulfuric acid concentration, M	Total hexoses, %	Total solids, %	Aldehydes, %	Sulfuric acid, %
- (initial sample)	3.7	7.8	5.5	0.8
0.05	7.3	6.7	2.9	1.0
0.2	6.8	7.3	5.2	2.3
0.5	7.2	8.8	9.9	5.2

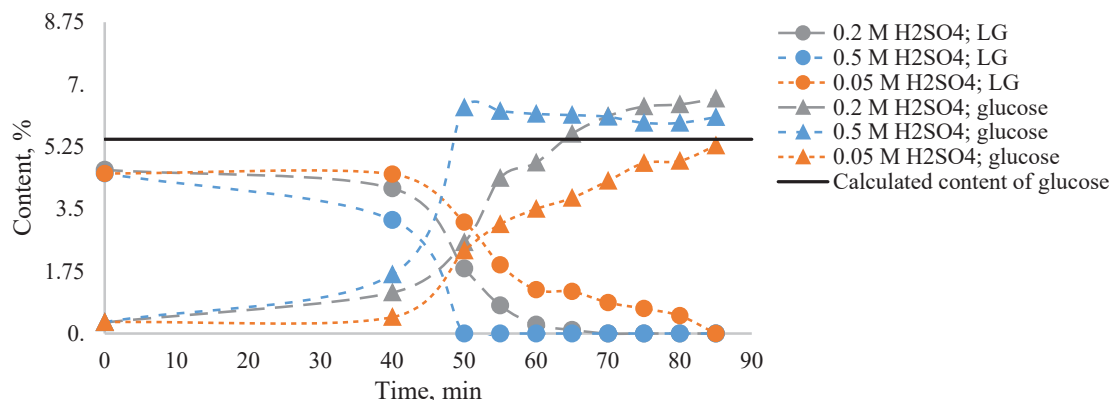


Figure 4. Levoglucosan and glucose content (%) change in time during acid hydrolysis using different sulfuric acid concentrations at 121 °C.

previously (Figure 5). Similarly, as in HPLC-RI results, increased catalyst content decreases the time in which the total hexoses reach maximum but does not increase the total content at the end. Reaction rate constant at this temperature was 0.056 min⁻¹, 0.197 min⁻¹ and 0.204 min⁻¹ using catalyst with 0.05 M; 0.2 M and 0.5 M concentration respectively. These results show that increasing the catalyst concentration beyond 0.2 M does not increase the rate of levoglucosan hydrolysis.

At 131 °C, increase of catalyst concentration increases the total aldehyde concentration in the

sample but does not increase the total hexoses content in the sample when hydrolysis is complete (Table 3).

At 131 °C best results were obtained using 0.2 M sulfuric acid as catalyst with only minor differences between both catalyst concentrations (Figures 6, 7). When comparing conditions at both 121 °C and 131 °C, using 0.2 M catalyst, it can be observed that at 131 °C there is a more pronounced increase in the glucose content after levoglucosan has fully hydrolyzed. Reaction rate constant for levoglucosan hydrolysis at 131 °C was detected to be 0.224 min⁻¹.

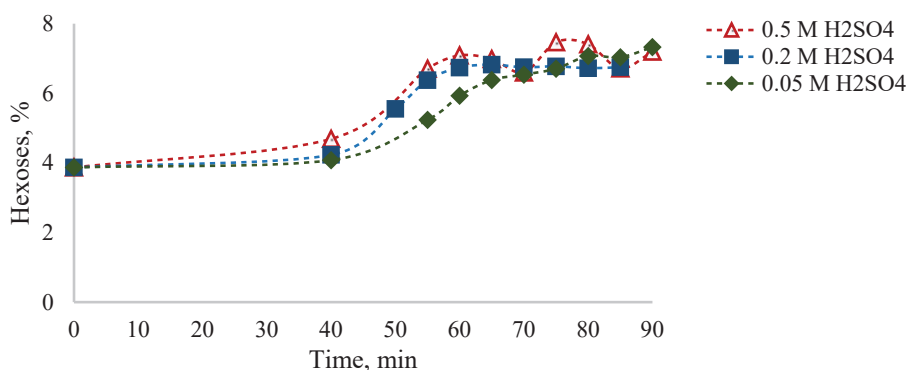


Figure 5. Increase of total hexoses content (%) in time during acid hydrolysis using different sulfuric acid concentrations at 121 °C.

Table 3

Characteristic parameters of the hydrolyzed pyrolysis liquid sample using different sulfuric acid concentrations at 131 °C

Sulfuric acid concentration, M	Total hexoses, %	Total solids, %	Aldehydes, %	Sulfuric acid, %
- (initial sample)	3.7	7.8	5.5	0.8
0.1	7.5	6.4	3.5	1.5
0.2	7.0	7.3	5.0	2.5

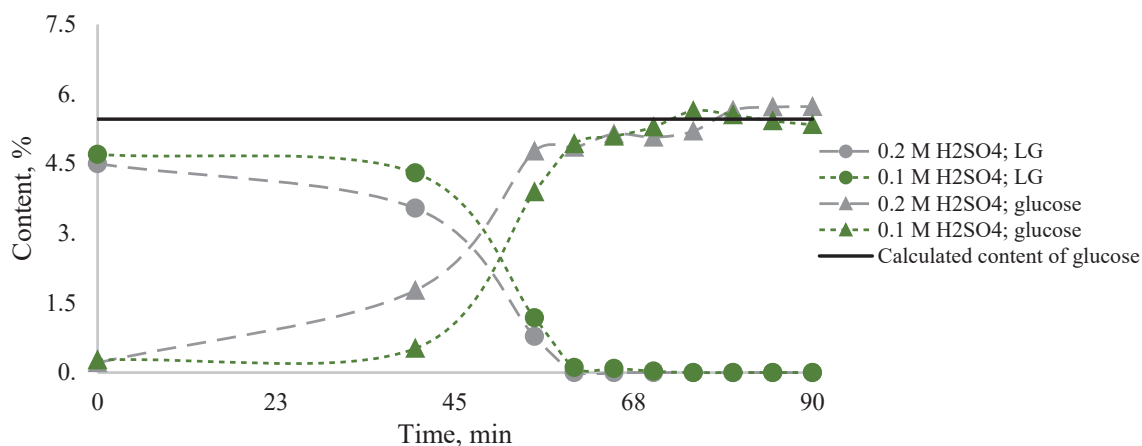


Figure 6. Levoglucosan and glucose content (%) change in time during acid hydrolysis using different sulfuric acid concentrations at 131 °C.

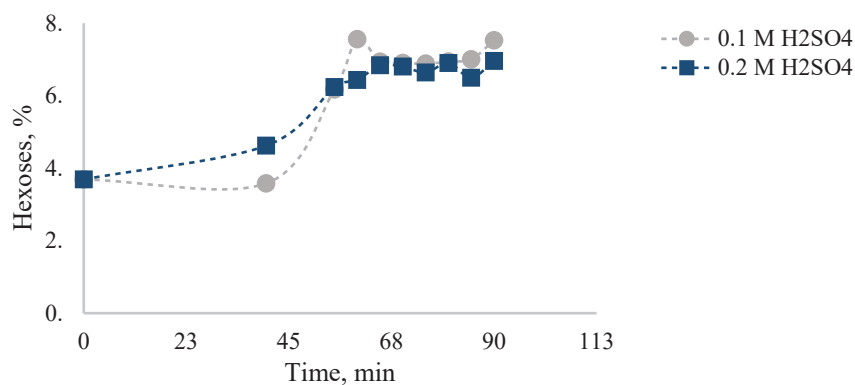


Figure 7. Increase of total hexoses content (%) in time during acid hydrolysis using different sulfuric acid concentrations at 131 °C.

Conclusions

1. For the purpose of this study, a method for determining glucose and levoglucosan content in hydrolyzed bio-oil samples were adapted and partially validated in accordance to EuroChem method validation guidelines. All analytical parameters of the obtained method analytical parameters were in acceptable range allowing to conclude that this method is fit for the purpose.
2. Optimal condition for obtaining maximal glucose content from bio-oil samples was 121 °C with 0.2 M

sulfuric acid as a catalyst. Using above mentioned conditions, the total glucose concentration in the sample after hydrolysis was 6.6% that exceeds calculated glucose amount of 5.5% meaning in addition to LG there are other sources of glucose being hydrolyzed in these conditions.

3. Obtained results allows us to conclude that by combining fast pyrolysis with acid hydrolysis it is possible to transform lignocellulosic biomass into a form suitable for use in biofuel obtaining.

References

- Aden, A., Ruth, M., Ibsen, K., Jechura, J., Neeves, K., Sheehan, J., Wallace, B., Montague, L., Slayton, A., & Lukas, J. (2002). National Renewable Energy Laboratory, Golden, CO, NREL/TP-510-32438.
- Bennett, N.M., Helle, S.S., & Duff, S.J. (2009). Extraction and hydrolysis of levoglucosan from pyrolysis oil. *Bioresour. Technol.* 100(23), 6059–6063. DOI: 10.1016/j.biortech.2009.06.067.
- Bridgwater, A.V. (1999). Principles and practice of biomass fast pyrolysis process for liquids. *J. Anal. Appl. Pyrolysis.* 51(1-2), 3–22. DOI: 10.1016/S0165-2370(99)00005-4.
- Czernik, S., & Bridgwater, A. (2004). Overview of applications of biomass fast pyrolysis oil. *Energy Fuels.* 18(2), 590–598. DOI: 10.1021/ef034067u.

- Helle, S., Bennett, N.M., Lau, K., Matsui, J.H., & Duff, S.J. (2007). A kinetic model for production of glucose by hydrolysis of levoglucosan and cellobiosan from pyrolysis oil. *Carbohydr. Res.* 342(16), 2365–2370. DOI: 10.1016/j.carres.2007.07.016.
- Huber, G.W., Chheda, J.N., Barrett, C.J., & Dumesic, J.A. (2005). Production of liquid alkanes by aqueous-phase processing of biomass-derived carbohydrates. *Science.* 308(5727), 1446–1450. DOI: 10.1126/science.1111166.
- Huber, G.W., Iborra, S., & Corma, A. (2006). Synthesis of Transportation Fuels from Biomass: Chemistry, Catalysts, and Engineering. *Chem. Rev.* 106(9), 4044–4098. DOI: 10.1021/cr068360d.
- Isikgor, F.H., & Becer, C.R. (2015). Lignocellulosic biomass: a sustainable platform for the production of bio-based chemicals and polymers. *Polym. Chem.* 6(25), 4497–4559. DOI: 10.1039/C5PY00263J.
- Lian, J., Chen, S., Zhou, S., Wang, Z., O’Fallon, J., Li, C., & Garcia-Perez, M. (2010). Separation, hydrolysis and fermentation of pyrolytic sugars to produce ethanol and lipids. *Bioresour. Technol.* 101(24), 9688–9699. DOI: 10.1016/j.biortech.2010.07.071.
- LR Zemkopības ministrija. (2018). Meža Nozare Skaitļos un Faktos. Retrieved February 16, 2020, from <https://www.zm.gov.lv/mezi/statiskas-lapas/nozares-informacija/buklets-meza-nozare-skaitlos-un-faktos?id=1106#jump>.
- Magnusson, B., & Örnemark, U. Eurachem Guide: The Fitness for Purpose of Analytical Methods – A Laboratory Guide to Method Validation and Related Topics, (2nd ed. 2014). ISBN 978-91-87461-59-0. Retrieved February 16, 2020, from <http://www.eurachem.org>.
- Meile, K., & Zhurinsh, A. (2016). Preparative Solid Phase Extraction for the Purification of Levoglucosan Obtained from Lignocellulose. *Key Engineering Materials.* 721, 82-86. DOI: 10.4028/www.scientific.net/KEM.721.82.
- Mettler, M.S., Paulsen, A.D., Vlachos, D.G., & Dauenhauer, P.J. (2012). Pyrolytic conversion of cellulose to fuels: levoglucosan deoxygenation via elimination and cyclization within molten biomass. *Energy Environ. Sci.* 5(7), 7864–7868. DOI: 10.1039/C2EE21305B.
- Mohan, D., Pittman, C.U., & Steele, P.H. (2006). Pyrolysis of Wood/Biomass for Bio-oil: A Critical Review. *Energy Fuels.* 20(3), 848–889. DOI: 10.1021/ef0502397.
- Mosier, N., Wyman, C., Dale, B., Elander, R., Lee, Y.Y., Holtzapple, M., & Ladisch, M. (2005). Features of promising technologies for pretreatment of lignocellulosic biomass. *Bioresour. Technol.* 96(6), 673–686. DOI: 10.1016/j.biortech.2004.06.025.
- Oasmaa, A., & Czernik, S. (1999). Fuel oil quality of biomass pyrolysis oils state of the art for the end users. *Energy Fuels.* 13(4), 914–921. DOI: 10.1021/ef980272b.
- Ragauskas, A.J., Williams, C.K., Davison, B.H., Britovsek, G., Cairney, J., Eckert, C.A., Frederick, W.J. Jr, Hallett, J.P., Leak, D.J., Liotta, C.L., Mielenz, J.R., Murphy, R., Templar R., & Tschaplinski, T. (2006). The path forward for biofuels and biomaterials. *Science.* 311(5760), 484–489. DOI: 10.1126/science.1114736.
- Sipilä, K., Kuoppala, E., Fagernäs, L., & Oasmaa, A. (1998). Characterization of biomass-based flash pyrolysis oils. *Biomass Bioenergy.* 14(2), 103–113. DOI: 10.1016/S0961-9534(97)10024-1.
- Schuler, J., Hornung, U., Dahmen, N., & Sauer, J. (2019). Lignin from Bark as a Resource for Aromatics Production by Hydrothermal Liquefaction. *GCB Bioenergy.* 11 (1), 218–229. DOI: 10.1111/gcbb.12562.

THE COMPARISON OF THE SPRAY-DRYING AND FREEZE-DRYING TECHNIQUES FOR CAMEL MILK: A REVIEW

Uklim Tastemirova¹, *Inga Ciprova², Azaret Shingisov³

¹Almaty Technological University, Kazakhstan

²Latvia University of Life Sciences and Technologies, Latvia

³M.Auezov South Kazakhstan State University, Kazakhstan

*Corresponding author's email: inga.ciprova@llu.lv

Abstract

The aim of the present study was to analyse and compare camel milk powder quality and functional properties produced with spray-drying and freeze-drying techniques. Freeze-drying is recognized as an advanced method for the production of high-quality dried products, but it has been a costly process for production of camel milk powder. Spray-drying and freeze-drying of camel's milk demonstrated that the nutritional characteristics of this product basically remained unchanged compared to fresh milk. The differences were found analysing flowability, solubility and hygroscopicity of camel milk powder samples obtained with freeze-drying and spray-drying technique. Analysed quality indices of camel milk demonstrated that spray-drying has lower impact on camel milk powder physical properties in comparison with freeze-drying.

Key words: camel milk, spray-drying, freeze-drying.

Introduction

In 2018, the world market for camel milk products reached the value of 5.64 billion USD, growing of 3.89% during 2011–2018 (Camel dairy market, 2019). The camel milk price is significantly higher compared to cow milk, as production of camel milk is lower, but production costs are higher. Nutritional benefits of camel milk significantly outweigh the production costs.

Camel milk is nutritiously dense product, characterises with lower fat and cholesterol, and higher protein content. Milk contains more whey proteins such as lactoferrin and immunoglobulins. On average, camel milk consists of more protein than cow milk. Milk is rich with an essential amino acids, which have beneficial influence on human health. Camel milk has several times more vitamin C and iron than cow milk (Singh *et al.*, 2017). Some authors have established that the size of casein micelles and fat globules differs from cow milk (Farah & Fisher, 2004; Thomas, Scher, & Desobry, 2004). Clinical studies have shown that camel milk has a positive influence on children with autism spectrum disorder (Adams, 2013). Also, it was established that consumers with lactose intolerance easily metabolized lactose with lower incidence level (Singh *et al.*, 2017).

Camel milk products have been slowly gaining popularity across the world. Camel milk processors are also diversifying products which can be produce from camel milk. It is expected that global camel milk dairy market will grow up to 8.01% during 2020–2024, reaching 8 billion USD (Camel dairy market, 2019).

The main reason for production of camel milk powder is to prolong the shelf-life of product and to facilitate product storage and handling. The drying method of camel milk influences solubility of

powdered product. The shelf-life of camel milk powder is around 12 months, but skimmed milk powder more than 2 years (Farah & Fisher, 2004). The shelf-life of milk powder is established to warrant safety and to keep sensory properties like aroma and flavour. Milk powder is microbiologically stable product but some physicochemical properties like lactose crystallisation, particles caking, oxidation of fat, and Maillard reaction may occur during the shelf-life. Changes which occur during milk powder storage influence physical and functional properties, reconstitution process as well as emulsifying and foaming properties. The level of changes is strongly dependent on the storage conditions: temperature, relative air humidity and storage time. The understanding of changes that occur during milk powder production and storage will be valuable to predict the behaviour of milk powder during reconstitution process (Thomas, Scher, & Desobry, 2004).

In practice, spray-drying is used for camel milk powder production but in recent years freeze-drying is practised for camel milk functional properties' preservation.

The aim of the present study was to analyse and compare camel milk powder quality and functional properties produced with spray-drying and freeze-drying techniques.

Materials and Methods

The monographic method was used to summarise and analyse the latest information and research articles dedicated to camel milk drying. The published data were used for compilation of commercially available dairy products made from freeze-dried camel milk; in addition, the physical properties of camel milk powder were studied for reconstituted milk products production.

Results and Discussion

Freeze and spray drying are processing methods which convert milk into powder. Each method affects the physicochemical characteristics of dried milk. Spray drying is a widely used drying method, because a very short time of heat contact and high rate of evaporation are needed that give a high-quality product with a relatively low cost. Freeze-drying is a process in which water is removed from a frozen solution by sublimation. Due to the vacuum, the ice will evaporate immediately without turning into water, and this ensures that all solid compounds will be considered as the costliest process for production of dried products (Kim, Chang, & Kwan, 2010; Rogers *et al.*, 2008; Carvalho *et al.*, 2007; Boss *et al.*, 2004; Tsinontides *et al.*, 2004). Freeze-drying is applied for drying heat sensitive foods and biologically active compounds. This process minimizes the degradation reactions and maintains adequate physical, chemical and biological stability of the product during long-term storage (Fonseca *et al.*, 2004). Freeze-drying is recognized as an advanced method for production of high-quality dried products.

The **main quality** criteria of milk powder is solubility, flowability, hygroscopicity and water activity, these parameters are compared in Table 1.

The freeze-dried camel’s milk showed higher insolubility compared to spray-dried camel milk. Insolubility usually must be below 0.2 ml in good

quality milk powder (CODEX STAN, 1999). Hausner ratio varied from 1.15 to 1.31 and from 1.21 to 1.37, correspondingly. Hausner ratio results are strong connection to powder flowability, a ratio of 1 to 1.25 indicated that powder had acceptable flowability, but ratio from 1.25 to 1.4 demonstrated rather well flowability (Sulieman *et al.*, 2018). All established values fall within free powder particles flowing. Also, powders differ in hygroscopicity. Hygroscopicity characterises the ability of dried product to absorb water molecules from environment. The hygroscopicity of studied powders also diverse, freeze-dried powders had more hygroscopicity which could be explained with structure of powder’s particles and higher bulk density. Analysed quality indices of camel milk demonstrated that spray-drying has lower impact on camel milk powder physical properties.

The camel milk powder composition is summarized in Table 2.

Nutritional properties of freeze-dried camel’s milk remained unchanged compared to raw milk (Ibrahim & Khalif, 2014).

The comparison of differently produced camel milk powder microstructure was provided in the review. Dried milk particles obtained with spray-drying technique showed average size conglomerates which consist of small merged sub-units (Figure 1a). Dried milk particles obtained with freeze-drying technique showed large size conglomerates which

Table 1

The influence of different drying techniques on camel milk powder quality

Drying technique	Insolubility, ml	Hausner ratio	a _w	Hygroscopicity
Spray-drying*	0.35–0.50	1.21–1.37	0.154–0.210	20.43–20.47
Freeze-drying**	0.65–0.85	1.15–1.31	0.253–0.340	22.32–27.32
Standard requirements***	≤ 0.20	--	--	--

*Sulieman *et al.*, 2014

**Sulieman *et al.*, 2018

***CODEX STAN 207–1999

Table 2

The comparison of differently produced camel milk powder composition (Sulieman *et al.*, 2014; Sulieman *et al.*, 2018)

Indices	Drying technique		Standard requirements***
	Spray-drying	Freeze-drying	
Total solids content, %	98.94–98.99	97.00–97.56	≥95.00
Moisture content, %	1.01–1.94	2.44–3.00	≤5.00
Protein content, %	24.10–26.73	23.54–25.30	≤25.00
Fat content, %	27.86–29.82	21.25–22.96	≤26.00

*** CODEX STAN 207–1999.

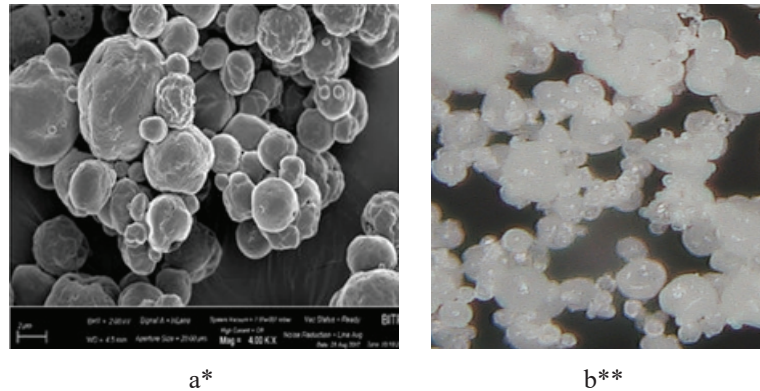


Figure 1. The microstructure of camel milk powder. a – spray-dried (Ho *et al.*, 2019)
b – freeze-dried (authors unpublished materials) *electronic microscopy, **3D microscopy.

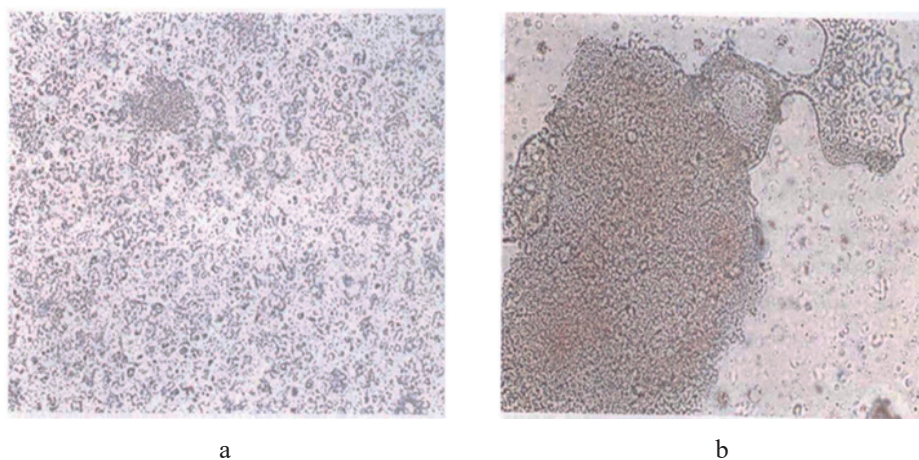


Figure 2. The microstructure of reconstituted milk (Simonenko, Manuilov, & Sidorova, 2019).
a – spray-dried, b – freeze-dried.

consist of many small merged units in bigger network (Figure 1b).

The results showed that camel milk powder had amorphous structure and spherical particles produced by spray drying. Freeze-dried milk consists of rough, regularly and irregularly shaped, and very voluminous particles. The microstructure analysis of camel milk powder confirms that drying process influences milk particles and their solubility (Kulazhanov *et al.*, 2014).

The reconstituted milk samples microstructure is shown in Figure 2.

The microstructure results showed that spray-dried milk reconstitution provide the full dispersion of milk constituents with the formation of homogeneous consistence (Figure 2a). The study of freeze-dried milk microstructure revealed that milk particles are hardly disintegrated (Figure 2b) and full solubility had not been achieved. The reconstituted milk

microstructure analyses showed the formation of large size conglomerates and the considerable coalescence of fat globules.

Conclusions

Freeze-drying is recognized as an advanced method of the production of high-quality dried products, but this process has been a costly process for production of camel milk powder.

Spray-drying and freeze-drying of camel's milk demonstrated that the nutritional value and chemical composition of this product basically remained unchanged compared to raw milk.

The differences were found analysing flowability, solubility and hygroscopicity of camel milk powder samples obtained with freeze-drying and spray-drying technique.

References

Adams, C.M. (2013). Patient report: autism spectrum disorder treated with camel milk. *Global Advance in Health and Medicine*, 2(6), 78–80.

- Akers, M.J., Fites, A.L., & Robinson, R.L. (1987). Types of parenteral administration. *Journal of Parenteral science and technology*, 41, 88–95.
- Boss, E.A., Filho, R.M., & Toledo, E.C. (2004). Freeze-drying process: real time model and optimization. *Chemical Engineering and Processing*, 43, 1475–1485.
- Camel Dairy Market: Global Industry Trends, Share, Size, Growth, Opportunity and forecast 2019–2024 (2019). p. 142.
- Carvalho, A.S., Silva, J., Ho, P., Teixeira, P., Malcata, F.X., & Gibbs, P. (2007). Relationship between solubility of freeze-dried skim milk and death of freeze-dried *Lactobacillus delbrueckii spp. bulgaricus* during storage. *Milchwissenschaft*, 62, 148–150.
- CODEX STAN 207–1999 (1999). Codex standard for milk powders and cream powder.
- Farah, Z., & Fisher, A. (2004). Milk and meat from the camel: Handbook on Products and Processing. Zurich: Vdf Hochschulverlag AG an der ETH Zurich, p. 230.
- Fonseca, F., Passot, S., Cunin, O., & Marin, M. (2004). Collapse temperature of freeze-dried *Lactobacillus bulgaricus* suspensions and protective media. *Biotechnology Progress*, 200, 229–238.
- Ho, T.M., Chan, S., Yago, A.J.E., Shrivya, R., Bhandari, B.R., & Bansal, N. (2019). Changes in physicochemical properties of spray-dried camel milk powder over accelerated storage. *Food Chemistry*, 295, 224–233.
- Ibrahim, A.H., & Khalif, S.A. (2014). Effect of freeze-drying on camels milk nutritional properties. *International Food Research Journal*, 22(4), 1438–1445.
- Kim, S-H., Chang, Y-H., & Kwak, H-S. (2010). Physicochemical properties of reconstituted milk made from freeze-dried milk powder or spray-dried milk powder. *Korean Journal of Food Science of Animal Resources*, 30, 28–35.
- Kulazhanov, K.S., Aralbayev, N.A., Dihanbayeva, F.D., Serikbayeva, A.D., & Yusof, Y.A. (2019). The study of solubility and density of camel milk powder, obtained by freeze-drying. Вестник АТУ, 3 (124), 47–51.
- Rogers, S., Wu, W.D., Saunders, J., & Chen, X.D. (2008). Characteristics of milk powders produced by spray freeze drying. *Drying Technology*, 26, 4040–412.
- Simonenko, S.V., Manuilov, B.M., & Sidorova, E.V. (2019). Most efficient method of drying combined milk. *International Research Journal*, Vol. 1, 9 (87), 116–121.
- Singh, R., Mal, G., Kumar, D., Patil, N.V., & Pathak, K.M.L. (2017). Camel milk: and important natural adjuvant. *Agricultural Research*, 6, 327–340.
- Sulieman, A.M., Elamin, O.M., Elkhalfifa, E.A., & Laleye, L. (2014). Comparison of physicochemical properties of spray-dried camel's milk and cow's milk powder. *International Journal of Food Science and Nutrition Engineering*, 4(1), 15–19.
- Sulieman, A.M., Elamin, O., Elkhalfifa, E.A., & Laleye, L. (2018). A comparative study of physicochemical properties of freeze-dried camel's milk and cow milk powder. *Journal of Agriculture and Food Science*, 6 (2), 11–16.
- Thomas, M.E.C., Scher, J., & Desobry, S. (2004). Milk powder ageing: effect on physical and functional properties. *Critical Reviews in Food Science and Nutrition*, 44 (5), 297–322.
- Tsinontides, S.C., Rajniak, P., Pham, D., Hinke, W.A., Placek, J., & Reynolds, S.D. (2004). Freeze drying – principles and practice for successful scale-up to manufacturing. *International Journal of Pharmacy*, 280, 1–16.

SMARTPHONE-BASED COLORIMETRIC DETERMINATION OF DPPH FREE RADICAL SCAVENGING ACTIVITY IN VEGETABLE OILS

*Sanita Vucane, Martins Sabovics, Lauris Leitans, Ingmars Cinkmanis

Latvia University of Life Sciences and Technologies, Latvia

*Corresponding author's email: sanitavucane@inbox.lv

Abstract

Free radicals can rapidly and irreversibly oxidize various structures, including unsaturated fatty acids in vegetable oils, which affect the sensory properties. Spectrophotometry is the most widely used method for the determination of free radical scavenging activity (RSA) using 2,2-diphenyl-1-picrylhydrazyl (DPPH). Barrier to the further use of classical analytical methods to analyze biologically active compounds in foodstuffs is that equipment requires high cost and has limited mobility. One of solutions is to replace classical methods, such as spectroscopy, with smartphone-based colorimetry. Huawei P30 Lite smartphone was used for colorimetric detection. The free radical scavenging activity (RSA) in vegetable oil was detected using an application 'Color Picker', with image matching algorithm for red, green, and blue (RGB) model. RSA was expressed as percentage and measured by the DPPH method. The aim of the study was to determinate the total free radical scavenging activity with smartphone-based colorimetry. For the data comparison and accuracy spectrophotometer as analytical optical instrument was used. Eleven vegetable oils: sea buckthorn, sunflower, rice, macadamia nut, hemp, corn, grape, linseed, rapeseed, olive and milk thistle oils were selected for analysis. The best results with no significant differences ($p > 0.05$) compared to smartphone-based colorimetry from spectrophotometry were determined using RG values. The poor results were detected by using B value ($p < 0.05$) and were not suitable for determination of RSA. Smartphone-based colorimetry can be used in the determination of the RSA in vegetable oils.

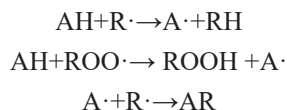
Key words: radical scavenging activity, digital image colorimetry, Android, Huawei, DPPH, vegetable oil.

Introduction

In analytical chemistry one of the most widely used methods for the determination of substances in coloured solution is spectroscopy. Spectroscopy has been a classical method for several years, but by the development of the smart digital equipment, there is a possibility to replace classical analytical methods with alternative methods. One of these alternatives is smartphones based on Android or iOS operating systems with good resolution cameras. Likewise, in spectroscopy, smartphone cameras and app algorithm can absorb the colour of light according to Beer-Lambert's law and can be used for colorimetric determination (Anderson, Bendell, & Groundwater, 2004). Smartphone based analysis is used in chemical analysis (Coskun *et al.*, 2012; Zhu *et al.*, 2011, Masawat *et al.*, 2015), paper-based strips (Yetisen *et al.*, 2014), dermatology (Kroemer *et al.*, 2011) and public health and safety (Jamalipour & Hossain, 2019). The colour of visible light depends on its wavelength. Human eyes can recognize a distinctive colour in the visible light of each wavelength. Only three colours – red (R), green (G) and blue (B) are primary and are needed to make the white colour. Red, green, and blue colours are known as the RGB colour model to construct the visible light. RGB colour model digitally describes the intensity of the visible light in pixels ranging from 0 to 255 (Rhyne, 2016). The use of RGB model system with smartphone-based colorimetry would play an important role in the determination of antioxidants. Antioxidants inhibit oxidation of foodstuffs, increase the shelf life and retain the original taste and smell characteristics (Farhoosh, 2005; Rajeswer Rao,

2015). Arteriosclerosis and tumor formations are facilitated by free radical-caused cell membrane and deoxyribonucleic acid (DNA) damage (Phaniendra, Jestadi, & Periyasamy, 2015). Free radicals can rapidly and irreversibly oxidize various structures, including unsaturated fatty acids that are components of the phospholipids in cell membranes (Jaswir, Che Man, & Kitts, 2000; Reische, Lillard, & Eitenmiller, 2002; Pelley, 2011; Rajeswer Rao, 2015). Plants, animal and human organisms have a strong defense system and physiological equilibrium between free radicals and antioxidants (Kelly *et al.*, 1995). For the protection against radicals in living organisms, it requires enzymes (catalase, glutathione peroxidase), proteins, thiols, glutathione, and antioxidants that are mainly absorbed through food. During inflammation, physical fatigue causes an increase of the formation of free radicals that facilitate damage to this physiological equilibrium system (Miyashita & Takagi, 1986; Goffman & Becker, 2001). It is proven that antioxidants are compounds that delay the formation of free radicals. In autooxidation processes oxygen in the air can spoil any fats that contain unsaturated fatty acids (Sies, 1991; Fürst, 1996; Abulude, Ogunkoya, & Eluyode, 2005; Aparicio & Harwood, 2013). Unsaturated fatty acids can easily react with air oxygen, and the product of primary oxidation is hydroperoxide that can actively react further. The speed of oxidation is greater, when there are more double bonds in fatty acid molecule (Wood *et al.*, 2002). It is possible to delay the autooxidation by the treatment of fat, using suitable packaging or adding antioxidants that can help to retain the sensory properties (Chen, Shi, &

Ho, 1992). Antioxidants (AH), when they react with radicals R· and ROO·, form a new and more stable radical A·, and the oxidation reaction is effectively slowed (Brand-Williams, Cuvelier, & Berset, 1995; St. Angelo *et al.*, 1996; Loftsson, 2014):



The polyunsaturated fatty acids within the vegetable oil easily oxidize, giving the oil a bitter taste. It is important to have an ability to capture the free radicals in oils to stop degrading processes that can change the quality of oils and its sensory properties, which can reduce biologically active compounds and consequently nutritional value. Nowadays, analytical methods used to analyze biologically active compounds in foodstuff, require expensive equipment with limited mobility. Due to research and advances in nanoparticles and new information technologies, it has been made possible to produce simple, portable, and low-cost equipment. One of solutions to characterize food quality and determine various biologically active compounds is to replace classical optical methods, such as spectroscopy, with smartphone-based colorimetry. The smartphones can compete with classical optical methods due to their high-resolution cameras (image quality 48 megapixels, in future up to 108 megapixels), ultra-highly sensitive optical and light sensors, and determination according to Beer-Lambert law.

The aim of the study was to determine the total free radical scavenging activity with smartphone-based colorimetry.

Materials and Methods

The principle of the colorimetric analysis of the research object is the digital imaging of vegetable oils prepared for the determination of free radical scavenging activity with smartphone-based application for colour analysis with Red, Green, Blue (RGB) colour model.

Samples: In total, eleven vegetable oils: sea buckthorn, sunflower, rice, macadamia nut, hemp, corn, grape, linseed, rapeseed, olive, and milk thistle oils in the original commercial packaging were selected for analysis.

Equipment for analysis: Agilent Cary 60 UV/VIS Spectrophotometer (Agilent Technologies, Inc., US) was used for the comparison with the smartphone Huawei P30 Lite (Huawei Technologies Co., Ltd., China) measurement.

For imaging, the smartphone Huawei P30 Lite (Huawei Technologies Co., Ltd., China) released 2019, April 25, operating system EMUI 10 (Android 10), 48-megapixel triple camera were used.

Image acquisition system: The digital image acquisition system consisted of a polyvinyl chloride PULUZ photo studio (Puluz Technology Ltd., China) softbox (24 × 32 × 38 cm³). Constant light intensity was provided by a 40 pieces light-emitting diode (LED) lamp (model 2835), with luminous flux 550 lm, colour temperature: 3200 K and power: 3.5 W. LED lamp was located at the upper part inside the lightbox. For taking a colorimetric image, a smartphone with a 48-megapixel camera (Huawei P30 Lite) was positioned outside in front of open side of the box at a distance of 12 cm from the PS 2.5 mL macro disposable cuvettes (BrandTech Scientific, Inc., US) with sample, DPPH reagent or 96% ethanol solution.

Imaging and image analysis: Image was captured by the smartphone camera and saved as 8-bit JPG format with the average size of 7.0 (8000 × 6000 pixels), ISO 400, f/1.8, 27 mm (wide), 1/2.0", 0.8 μm, PDAF (Phase Detection Autofocus). The image was analyzed by a RGB colour model, application for Android 'Color Picker', which was installed from Android Apps on Google Play store. The image analysis system was used to relate the colour change of the sample with DPPH reagent.

Determination of total free radical scavenging activity using 2,2-diphenyl-1-picrylhydrazyl (DPPH): The DPPH total free radical scavenging activity in the vegetable oil was determined according to the method reported by Ahmed *et al.* with slight modification (Ahmed, Khan, & Saeed, 2015).

DPPH reagent (Aldrich, Germany) with concentration 0.02 g L⁻¹ was freshly prepared in 96% ethanol every day and kept at 4 °C in refrigerator, in a volumetric flask protected from light until further use.

Determination of free radical scavenging activity in vegetable oils: 0.1 mL of vegetable oil were mixed with 3 mL of DPPH reagent in 15 mL 120 × 17 mm conical bottom PP tube (Sarstedt AG & Co.KG, Germany) and vortexed 30 sec. with IKA Vortex 3 (KA®-Werke GmbH & Co. KG, Germany) by speed 7. After 30 minutes of incubation in a dark place at room temperature (21±1 °C), tubes were centrifuged (Pro-Research, Centurion Scientific Ltd., UK) at 3000 rpm for 5 minutes and coloured solution was transferred to the PS 2.5 mL macro disposable cuvettes (BrandTech Scientific, Inc., US) with dimensions 12.5 × 12.5 × 45 mm. Absorbance of the sample against blank (96% ethanol) was measured at 517 nm using UV/VIS spectrophotometer Agilent Cary 60 (Agilent Technologies, Inc., US). Direct imaging of oil samples with DPPH reagent and 96% ethanol solution in cuvettes were captured using a smartphone-based colorimetric application by RGB colour model according to illustration of Figure 1.

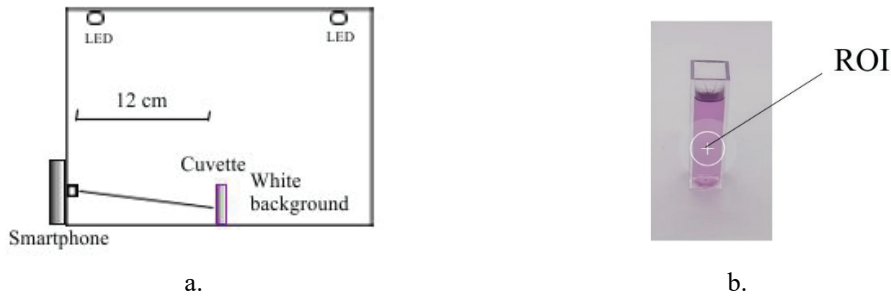


Figure 1. (a) Illustration of photo studio lightbox experimental setup for image acquisition; (b) example of region of interest (ROI) from a DPPH image.

Calculation method for determination of free radical scavenging activity with smartphone-based colorimetry

1) The obtained images from the smartphone application 'Color Picker' in RGB mode had an average colour value according to the equation reported by Jansons & Meija (Jansons & Meija,

2002) with modification for the individual red (R_{avg}), green (G_{avg}), and blue (B_{avg}), red-green (RG_{avg}), red-blue (RB_{avg}), green-blue (GB_{avg}) and red-green-blue (RGB_{avg}) colors by the equation 1, 2 and 3.

2) The average colour value of R_{avg} , G_{avg} , B_{avg} , RG_{avg} , RB_{avg} , GB_{avg} , RGB_{avg} was converted to absorbance by Beer-Lambert's equation 4 and 5 (Firdaus *et al.*, 2014).

$$R_{avg} = \frac{\sum_{i=1}^n R_i}{n} \quad \text{red } (R_{avg}) \quad G_{avg} = \frac{\sum_{i=1}^n G_i}{n} \quad \text{green } (G_{avg}) \quad B_{avg} = \frac{\sum_{i=1}^n B_i}{n} \quad \text{blue } (B_{avg}) \quad (1)$$

$$RG_{avg} = \frac{\frac{\sum_{i=1}^n R_i}{n} + \frac{\sum_{i=1}^n G_i}{n}}{2} \quad \text{red-green } (RG_{avg}) \quad RB_{avg} = \frac{\frac{\sum_{i=1}^n R_i}{n} + \frac{\sum_{i=1}^n B_i}{n}}{2} \quad \text{red-blue } (RB_{avg}) \quad GB_{avg} = \frac{\frac{\sum_{i=1}^n G_i}{n} + \frac{\sum_{i=1}^n B_i}{n}}{2} \quad \text{green-blue } (GB_{avg}) \quad (2)$$

$$RGB_{avg} = \frac{\frac{\sum_{i=1}^n R_i}{n} + \frac{\sum_{i=1}^n G_i}{n} + \frac{\sum_{i=1}^n B_i}{n}}{3} \quad \text{red-green-blue } (RGB_{avg}) \quad (3)$$

$$Abs_{DPPH} = -\log\left(\frac{I_{DPPH}}{I_0}\right) \quad (4)$$

where:

I_{DPPH} - R_{avg} , G_{avg} , B_{avg} , RG_{avg} , RB_{avg} , GB_{avg} or RGB_{avg} average colour value of DPPH after 30 min
 I_0 - R_{avg} , G_{avg} , B_{avg} , RG_{avg} , RB_{avg} , GB_{avg} or RGB_{avg} average color value of the blank (96% ethanol)

$$Abs_{DPPH} = -\log\left(\frac{I_{oil}}{I_0}\right) \quad (5)$$

where:

I_{oil} - R_{avg} , G_{avg} , B_{avg} , RG_{avg} , RB_{avg} , GB_{avg} or RGB_{avg} average colour value of vegetable oils with DPPH after 30 min
 I_0 - R_{avg} , G_{avg} , B_{avg} , RG_{avg} , RB_{avg} , GB_{avg} or RGB_{avg} average colour value of the blank (96% ethanol)

$$RSA = \left(\frac{Abs_{DPPH} - Abs_{oil}}{Abs_{DPPH}} * 100\right) = (\%) \quad (6)$$

where:

Abs_{DPPH} - R_{avg} , G_{avg} , B_{avg} , RG_{avg} , RB_{avg} , GB_{avg} or RGB_{avg} absorbance of DPPH after 30 min.
 Abs_{oil} - R_{avg} , G_{avg} , B_{avg} , RG_{avg} , RB_{avg} , GB_{avg} or RGB_{avg} absorbance of vegetable oil after 30 min.

3) Free radical scavenging activity (RSA) was calculated by equation 6, according to the method reported by Ahmed et.al. with slight modification (Ahmed, Khan, & Saeed, 2015).

Data Processing / Statistical Analysis

The data of the research was analyzed by the statistical and mathematical methods (mean, standard deviation). Data compared by the analysis of variance (ANOVA) and significance was defined at $p < 0.05$. For the data analysis, the Microsoft Excel software version 2016 was used. Samples were analyzed in five repetitions.

Results and Discussion

The individual and mix colour values in RGB model system was explored to find out the best colorimetric detection of free radical scavenging activity (RSA, %), because the CMOS image sensors in smartphones only detect red, green and blue colours (Kong *et al.*, 2019). Natural white colour consists of all three colours R-red, G-green, and B-blue, therefore, colour-white as calibration was used for background. Each primary color (Red, Green, Blue) in the RGB colour model has a pixel ranging from 0 to 255 and it means that the white colour has the same pixel range as RGB colours or 255. Theoretically, if white background is used, the average RGB should be 255 pixels, but research showed that for 96% ethanol solution using white background, the average RGB decreases to 180 pixels. Decrease in the pixel range is dependent on the concentration and used light, which is related to the used light in photography lightbox studio PULUZ with light-emitting diode (LED) colour temperature 3200 K and smartphone image parameters for the camera. Results in Table 1 show that sensitivity of blue (B) value differed from red (R), and green (G) colours, except, Macadamia nut oil. Detected free radical scavenging activity of Macadamia nut oil by smartphone-based colorimetry was $47.3 \pm 0.6\%$ and by UV/Vis spectrophotometry it was $45.9 \pm 0.1\%$. The difference between used methods was only 1.4%. Different sensitivity of B values was expressed with

R or G, respectively RB and GB values, showed poor results ($p < 0.05$) comparing to another RG values and UV/Vis spectrophotometry for all vegetable oils. Therefore, B, RB and GB values could not be used for the calculation of RSA for vegetable oils. 2,2-diphenyl-1-picrylhydrazyl (DPPH) is a stable free radical with scavenging capabilities of antioxidants from vegetable oils, which can donate a hydrogen to form the stable DPPH-H molecule. Absorbance decreased as colour changed from violet to pale yellow in the wavelength that ranged from 405 to 520 nm (Kumara, Sunil, & Kumar, 2018). DPPH reacts with an antioxidant to form a yellow colour; however, maximum wavelength absorbance for classical UV/Vis spectrometry is measured only by one spectrum at 517 nm. Smartphone-based colorimetry can detect a wider visible light spectrum from 400 to 700 nm wavelength; therefore, complementary colour for analysis is needed (Turgeon, 2014). Colour wheel shows that complementary colour to violet colour is yellow (Figure 2), but only three colours red (R), green (G) and blue (B) are primary and can be directly imaged with Android application ‘Color Picker’; therefore, in case of the determination of RSA, a colour that closely matches the complementary yellow colour should be chosen. Green colour is close to primary colours, and to achieve better analytical results, a coloured-light mixing with primary colour red to obtain yellow colour should be used.

UV/VIS spectroscopy was used in comparison with smartphone-based colorimetry. Results show (Table 1) that analysis has a difference in range to 66.7% of RSA. The best results were obtained for RSA in RG values, and calculated *t*-value for smartphone-based colorimetry was lower than the critical *t*-value (0.47, $p > 0.05$); therefore, no statistical difference at a 95% confidence level between the free radical scavenging activity by using the smartphone-based colorimetry and the UV/Vis spectroscopy for the analysis was observed. The highest free radical scavenging activity in vegetable oils was determined by UV/Vis spectroscopy and Smartphone-based colorimetry



Figure 2. Colour wheel of primary and secondary colours.

Table 1

Comparison of free radical scavenging activity (%RSA) by UV/Vis and Smartphone-based colorimetry with different color values from RGB modules

Vegetable oils	Method							
	UV-Vis	Smartphone-based colorimetry						
	Free radical scavenging activity (RSA), %							
		R	G	B	RG	RB	GB	RGB
Sea buckthorn	93.5±0.1	94.8±0.7	91.7±0.7	67.0±0.6	93.2±0.7	80.9±0.6	79.3±0.6	84.5±0.6
Sunflower	80.7±0.1	85.2±0.6	76.1±0.6	40.6±0.6	80.7±0.6	62.9±0.6	58.4±0.6	67.3±0.6
Rice	67.6±0.1	74.8±0.7	59.5±0.7	0.9±0.6	67.2±0.6	37.9±0.6	30.2±0.6	45.0±0.7
Macadamia nut	45.9±0.1	66.8±0.6	23.4±0.6	47.3±0.6	45.1±0.6	57.0±0.6	35.4±0.6	45.8±0.6
Hemp	95.7±0.1	96.0±0.7	95.0±0.7	68.1±0.6	95.5±0.7	82.0±0.6	82.0±0.6	86.4±0.6
Corn	61.5±0.1	74.8±0.6	47.9±0.8	1.3±0.6	61.3±0.6	38.0±0.6	24.6±0.6	41.3±0.6
Grape	73.3±0.1	84.2±0.6	61.6±0.6	34.4±0.6	72.9±0.6	59.3±0.6	48.0±0.6	43.4±0.6
Linseed	68.3±0.1	77.4±0.6	59.5±0.6	15.3±0.6	68.5±0.6	46.4±0.6	37.4±0.6	52.3±0.6
Rapeseed	91.4±0.1	89.7±0.6	93.6±0.7	46.1±0.6	91.7±0.7	67.9±0.6	69.9±0.6	76.5±0.6
Olive	95.7±0.1	96.0±0.7	95.0±0.7	68.1±0.6	95.5±0.7	82.0±0.6	82.0±0.6	86.4±0.6
Milk thistle	94.3±0.1	96.9±0.6	92.2±0.6	80.0±0.7	94.6±0.6	88.5±0.6	86.1±0.6	89.7±0.6

using a RG values, respectively, hemp 95.7±0.1%-95.5±0.7%, olive 95.7±0.1%-95.5±0.7%, milk thistle 94.3±0.1%-94.6±0.6%, sea buckthorn 93.5±0.1%-93.2±0.7% and rapeseed 91.4±0.1%-91.7±0.7% oils, but the lowest activity was detected in macadamia nut 45.9±0.1%-45.1±0.6%, corn 61.5±0.1%-61.3±0.6% and rice 67.6±0.1%-67.2±0.6% oils. Precision of imaging method was evaluated by relative standard deviation (%RSD). Using UV/Vis spectroscopy for the analysis, the value of RSD was lower and showed better sensitivity: 0.1%, although the RSD for smartphone-based colorimetry was higher and ranged from 0.6 to 0.7%. Unfortunately, in literature, there is lack of scientific researches reporting the determination of free radical scavenging activity using a smartphone-based colorimetry.

Conclusions

In the reported research, a new methodology for the determination of free radical scavenging activity based on the smartphone-based colorimetry was obtained. The principle of this method is to analyze a digital imaging of RSA in vegetable oils with DPPH, which is obtained with a smartphone camera, and show the results in application for colour analysis with RGB colour model using only RG values. Although UV/Vis spectroscopy has better sensitivity, the results showed that smartphone-based colorimetry in RG values can be used for the determination of RSA. Smartphone-based colorimetry is simple, portable, and low cost; therefore, it is necessary to develop new detection methods for various chemical analysis based on the principle of analysis of smartphone-based digital images.

References

- Abulude, F.O., Ogunkoya, M.O., & Eluyode, O.S. (2005). Effect of storage on the physicochemical properties of palm oil. *Pakistan Journal of Scientific and Industrial Research*. Pakistan Council of Scientific and Industrial Research (PCSIR), Karachi, Pakistan: 48:2, 5.ref. 110–112.
- Ahmed, D., Khan, M.M., & Saeed, R. (2015). Comparative Analysis of Phenolics, Flavonoids, and Antioxidant and Antibacterial Potential of Methanolic, Hexanic and Aqueous Extracts from *Adiantum caudatum* Leaves. *Antioxidants* 2015, 4, 394–409. DOI: 10.3390/antiox4020394.
- Farhoosh, R. (2005). Antioxidant activity and mechanism of action of butein in linoleic acid. *Food Chemistry*, Vol. 93, Issue 4, 633–639. DOI: 10.1016/j.foodchem.2004.10.041.
- Anderson, R.J., Bendell, D.J., & Groundwater, P.W. (2004). *Organic Spectroscopic Analysis*. Royal Society of Chemistry; 1 edition, 8. Cambridge: The Royal Society of Chemistry.
- Brand-Williams, W., Cuvelier, M.E., & Berset, C. (1995). Use of a free-radical method to evaluate antioxidant activity. *Lebensmittel-Wissenschaft und-Technologie*, 28 (1), 25–30. DOI: 10.1016/S0023-6438(95) 80008-5.

- Chen, Q., Shi, H., & Ho, C.T. (1992). Effects of rosemary extracts and major constituents on lipid oxidation and soybean lipoxygenase activity. *Journal of the American Oil Chemists' Society*, Vol. 69 (10), 999–1002. DOI: 10.1007/BF02541065.
- Firdaus, M.L., Alwi, W., Trinoveldi, F., Rahayu, I., Rahmidar, L., & Warsito, K. (2014). Determination of Chromium and Iron Using Digital Image-based Colorimetry. *Procedia Environmental Sciences*, 20, 298–304. DOI: 10.1016/j.proenv.2014.03.037.
- Fürst, P. (1996). The role of antioxidants in nutritional support. *Proceedings of the Nutrition Society*, 55, 945–961. DOI: 10.1079/PNS19960091.
- Goffman, F.D., & Becker, H.C. (2001). Diallel analysis for tocopherol contents in seeds of rapeseed. *Crop Science*, 41, 1072–1079.
- Jamalipour, A., & Hossain, M.A. (2019). *Smartphone Instrumentations for Public Health Safety*. Cham: Springer Nature Switzerland.
- Janson, E., & Meija, J. (2002). *Kļūdas kvantitatīvajās noteikšanās (Errors of quantitative determinations)*. Rīga: Rasa ABC. (in Latvian).
- Jaswir, I., Che Man, Y.B., & Kitts, D.D. (2000). Optimization of physicochemical changes of palm olein with phytochemical antioxidants during deep-fat frying. *Journal of the American Oil Chemists' Society*, Vol. 77 (11), 1161–1168. DOI: 10.1007/s11746-000-0182-6.
- Kelly, F.J., Mudway I., Krishna, M.T., & Holgate, S.T. (1995). The free radical basis of air pollution: focus on ozone. *Respiratory Medicine*, 89, 647–656. DOI: 10.1016/0954-6111(95)90131-0.
- Kong, T., You, J.B., Zhang, B., Nguyen, B., Tarlan, F., Jarvi, K., & Sinton, D. (2019). Accessory-free quantitative smartphone imaging of colorimetric paper-based assays. *Lab on a Chip*. 19(11), 1991–1999. DOI: 10.1039/C9LC00165D.
- Kroemer, S., Fruhauf, J., Campbell, T.M., Massone, C., Schwantzer, G., & Soyer, H.P. (2011). Mobile teledermatology for skin tumour screening: diagnostic accuracy of clinical and dermoscopic image tele-evaluation using cellular phones, *British Journal of Dermatology* 164. 973–979. DOI: 10.1111/j.1365-2133.2011.10208.x.
- Kumara, P., Sunil, K., & Kumar, A. (2018). Determination of DPPH Free Radical Scavenging Activity by RP-HPLC, Rapid Sensitive Method for the Screening of Berry Fruit Juice Freeze Dried Extract. *Natural Products Chemistry & Research*. Volume 6, Issue 5, 1–7. DOI: 10.4172/2329-6836.1000341.
- Loftsson, T. (2014). Autoxidation (auto-oxidation) is a complex oxidation mechanism that proceeds through a free radical chain process. *Drug Stability for Pharmaceutical Scientists*. Oxford: Academic press.
- Miyashitau, K., & Takagi, T. (1986). Study on the oxidative rate and prooxidant activity of free fatty acids. *Journal of the American Oil Chemists' Society*, 63, 1380–1384.
- Pelley, J.W. (2011). Fatty Acid and Triglyceride Metabolism. Elsevier's Integrated Review Biochemistry (Second Edition). Philadelphia: Elsevier Saunders.
- Phaniendra, A., Jestadi, D.B., & Periyasamy, L. (2015). Free Radicals: Properties, Sources, Targets, and Their Implication in Various Diseases. *Indian Journal of Clinical Biochemistry*. 30(1), 11–26.
- Rajeswer Rao, V. (2015). Chapter 7 – Antioxidant Agents. *Advances in Structure and Activity Relationship of Coumarin Derivatives*. London: Academic Press.
- Reische, D.W., Lillard, D.A., & Eitenmiller, R.R. (2002). Antioxidants. In: Akoh, C.C. and Min, D.B., Eds., *Food Lipids: Chemistry, Nutrition and Biotechnology*. New York: Marcel Dekker.
- Rhyne, T.M. (2016). *Applying Color Theory to Digital Media and Visualization*. Boca Raton: CRC Press
- Sies, H. (1991). Oxidative stress II. Oxidants and Antioxidants. London: Academic Press.
- St. Angelo, A.J., Vercellotti, D.J., Jacks, T., & Legendre, M. (1996). Lipid oxidation in foods. *Critical Reviews in Food Science and Nutrition* 36, 175–224. DOI: 10.1080/10408399609527723.
- Turgeon, M.L. (2014). Linne & Ringsrud's Clinical Laboratory Science: *The Basics and Routine Techniques*. Missouri: Elsevier Mosby.
- Wood, L.G., Fitzgerald, D.A., Lee, A.K., & Garg, M.L. (2002). Improved antioxidant and fatty acid status of patients with cystic fibrosis after antioxidant supplementation is linked to improved lung function. *American Journal of Clinical Nutrition*, 77, 150–159. DOI: 10.1093/ajcn/77.1.150.
- Yetisena, A.K., Martinez-Hurtadoa, J.L., Garcia-Melendrezb, A., da Cruz Vasconcellosa, F., & Lowea, C.R. (2014). A smartphone algorithm with inter-phone repeatability for the analysis of colorimetric tests. *Sensors and Actuators B* 196, 156–160. DOI: 10.1016/j.snb.2014.01.077.

α -AMYLASE ACTIVITY IN FREEZE-DRIED AND SPRAY-DRIED HONEY

*Anete Keke, Ingmars Cinkmanis

Latvia University of Life Sciences and Technologies, Latvia

*Corresponding author's email: anete.keke@llu.lv

Abstract

Honey is a naturally supersaturated sugar solution, which tends to crystallize. The crystallization of honey can lead to unwanted fermentation that can have a negative impact to honey quality. The production of honey powder could be an alternative method to prevent honey from fermentation. Honey powder could be used as alternative substitute to liquid honey that would allow to use this product more widely in the food industry. α -amylase activity is one of the most important parameters to evaluate the quality of honey. The aim of this study was to investigate the effect of freeze-drying and spray-drying on honey α -amylase activity. Detection of α -amylase activity was carried out by spectrophotometric method. High-performance liquid chromatography was used to determine the content of hydroxymethylfurfural in the powders. The obtained results showed that both drying methods had a negative impact to the enzyme activity in the samples. The lowest activity of α -amylase (8.3 DN) was measured in the spray-dried honey powder. Concentration of hydroxymethylfurfural (HMF) in the powders did not exceed required concentration 40 mg kg⁻¹.

Key words: α -amylase activity, freeze drying, spray drying, honey, HMF.

Introduction

Honey is well-known food product over the world due to its sweet taste, aroma, and health benefits. Moreover, honey is chemically complex food product, which consists of approximately 200 substances (Geana & Ciucure, 2020). Fructose and glucose are the main constituents of honey. There is also a wide range of minor components that are present in honey such as enzymes, organic acids, amino acids, phenolic compounds, etc. Honey quality and chemical composition depend on the floral and geographical origin, climate and processing (Sakač *et al.*, 2018).

As a supersaturated sugar solution, honey tends to spontaneously crystallize. The spontaneous crystallization of honey increases water activity, which can lead to unwanted fermentation (Tappi *et al.*, 2019). The unwanted fermentation can negatively affect the quality of honey. Thermal processing is often used to prevent the negative effect of crystallization (Tosi *et al.*, 2004; Ribeiro *et al.*, 2018). Thermal methods could be used to transform liquid honey into powdered honey by drying. This is an alternative method that could be used to preserve honey. Moreover, powdered honey has many advantages such as ease of packaging and handling, prolonged shelf life, expanded usage in the food industry (Kilinç & Demir, 2017). The production of honey in a powdered form is challenging due to its high concentration of sugars and organic acids. Sugar-rich products such as honey tends to form lumps or syrup during the drying process (Samborska, 2019). Different drying aids such as maltodextrin, whey protein isolate, Arabic gum are added to honey to increase the glass transition temperatures (Shi, Fang, & Bhandari, 2013; Muzaffar, 2015). The concentration of drying aids in honey powder cannot be lower than 50% of solids to successfully perform the drying of honey (Bhandari, Datta, & Howes, 1997). Samborska and co-workers (Samborska, Sokołowska, & Szulc,

2017a) reported that pre-treatment methods such as diafiltration can be used to obtain powder, which contains 75% of honey.

Dehydrated honey can be produced by vacuum drying, microwave vacuum drying, freeze-drying and spray drying (Cui *et al.*, 2008; Nurhadi & Roos, 2016; Sramek *et al.*, 2016). Spray drying is widely used to obtain honey powder. The method is very popular due to its cost effectiveness, short production time and high product quality (Jedlińska *et al.*, 2019; Samborska, 2019). Freeze-drying is an especially useful drying technique to preserve bioactive compounds. Unfortunately, due to the methods expensiveness and long production time, freeze-drying is rarely used to produce honey powder (Subramanian, Hebbar, & Rastogi, 2007).

Enzymatic activity is an important indicator to evaluate the quality of honey. Enzymes are very sensitive to thermal processing, which can lead to loss of enzymatic activity of honey (Kowalski & Lukaszewicz, 2017). α -amylase, which is predominant enzyme in honey, can be inactivated by thermal treatments at 80 °C for 1.2 hours (Schade, Marsh, & Eckert, 1958; Tosi *et al.*, 2004). α -amylase (diastase) activity is the main indicator to evaluate the quality of honey as well as authenticity. According to the Council of the European Union Directive relating to honey 2001/110/EC, α -amylase activity is required not to be lower than 8 DN. Diastase number (DN) in Schade scale is defined as grams of starch hydrolysed during one hour at 40 °C (Kowalski *et al.*, 2012). Hydroxymethylfurfural is another important indicator that is used along with α -amylase activity to evaluate the quality of honey (Pasiak, Kiriakou, & Proestos, 2017).

The aim of this study was to investigate the effect of freeze-drying and spray-drying on honey α -amylase activity.

Table 1

Chemical composition of multifloral honey

Free acidity, meq kg ⁻¹	pH	Moisture content, %	α -amylase activity, DN	Fructose, g 100 g ⁻¹	Glucose, g 100 g ⁻¹	HMF, mg kg ⁻¹
42.0±1.0	3.66±0.01	20.5±0.2	18.5±0.3	36.4±0.2	31.8±0.2	41.4±0.5

Materials and Methods

The research was carried out in the scientific laboratory of Natural compounds and the scientific laboratory of Food processing engineering at the Faculty of Food Technology, the Latvia University of Life Sciences and Technologies.

Multifloral honey sample was delivered by the Latvian beekeeper of southern Latvia. The production year of honey was 2018. The main characteristic properties of the honey sample are shown in Table 1.

Maltodextrin (STAR-DRI® 10 NG, TATE & LYLE) was supplied by a local company (BANG & BONSOMER LATVIA, Rīga, Latvia). Dextrose equivalent (DE) of maltodextrin was 10.4, and moisture content was 4.3%. Maltodextrin was used as a carrier.

Obtaining freeze-dried and spray-dried honey

20% aqueous solutions of honey with maltodextrin were prepared for freeze-drying and spray-drying experiments. The ratio of honey and maltodextrin in the solutions was 1:2.

Freeze-drying of honey solution: the prepared solution was poured into a plastic freezer box, where the thickness of solution was approximately one centimetre. The freezer box was placed in the freezer for 2 hours at -20±1 °C. After 2 hours, the frozen sample was transferred to a freeze-dryer ALPHA 1-2 LDplus (MARTIN CHRIST Gefriertrocknungsanlagen GmbH, Germany). The freeze-drying process was performed under following conditions: the temperature of condenser was set to -50.6±0.5 °C and the pressure was 0.036 mbar. The duration of lyophilisation was 72 hours.

Spray-drying of honey solution: the prepared honey solution was spray-dried in BÜCHI mini spray drier B-290 (Labortechnik AG, Switzerland). The spray-drying process was carried out under following condition: the inlet air temperature was set to 180 °C, outlet temperature was 80 °C, sample speed rate was 15 mL min⁻¹.

After drying, the obtained powders were collected in polyethylene bags and stored in the dark and dry place at temperature of 20 °C until further analysis.

Determination of moisture content

One gram of obtained powders was weighted on glass fibre sheets and placed on the sample pan of moisture analyzer AND MX-50 (A&D Company, Limited, Japan). The moisture analysis was carried

out by heating up the samples at a drying temperature of 140 °C, the duration of analysis was 20 minutes. Moisture data was recorded using the software 'WinCT-Moisture'.

Determination of α -amylase activity

α -amylase activity was evaluated in liquid honey sample and obtained honey powders. The determination of α -amylase activity was performed by Amylzyme assay procedure (Megazyme, Ireland). The samples for analysis were prepared according to Amylzyme assay procedure. The absorbance of the analysed samples was measured by spectrophotometer Jenway 6405 UV/Vis (JENWAY, the U.K.) at 590 nm wavelength. The activity of the enzyme was calculated using the following formula:

$$\text{Schadeunits} = 20.0 \times \Delta \text{Abs} \quad (1)$$

where: is the absorbance of the sample at 590 nm.

Determination of hydroxymethylfurfural

The concentration of hydroxymethylfurfural was detected by high-performance liquid chromatography (HPLC). Honey and honey powder solutions were prepared at a concentration of 50 g L⁻¹. The analysis of the samples was performed using an analytical column PerkinElmer C18 (4.6 mm × 250 mm I.D., particle size 5 mm). The temperature of column and detector for the analysis was set to 25 °C. The mixture of acetonitrile (HPLC grade, Sigma-Aldrich) and deionized water (HPLC grade) was used as a mobile phase. The ratio of acetonitrile and deionized water was 10:90 (v/v). The analysis of the samples was carried out under isocratic conditions. Flow rate was 1.3 mL min⁻¹. The volume of the sample injection was 10 μ L, which was performed by autosampler SIL-20A. Detection of hydroxymethylfurfural carried out at 280 nm wavelength. The analysis was performed on Shimadzu LC-20 Prominence liquid chromatograph (Shimadzu USA Manufacturing Inc, Canby, USA) with a Shimadzu DAD SPD-M20A detector.

Determination of fructose and glucose content

Honey and honey powder solutions were prepared at a concentration of 50 g L⁻¹ to evaluate the content of fructose and glucose. The analysis of the sample was performed on Shimadzu LC-20 Prominence liquid chromatograph. The analytical column SUPELCOSIL™ LC-NH₂ (4.6 mm × 250 mm I.D., particle size 5mm). The temperature of column and detector was set to 30 °C. The mixture of acetonitrile

(HPLC grade, Sigma-Aldrich) and deionized water (HPLC grade) was used as a mobile phase. The ratio of acetonitrile and deionized water was 80:20 (v/v). The detection of glucose and fructose was performed under isocratic conditions. Flow rate was 1 mL min⁻¹. Injection volume of 10 μ L was performed using an autosampler SIL-20A. Shimadzu RID 10A Refractive Index detector was used to detect the presence of fructose and glucose in the samples.

Statistical analysis

All experiments were repeated in three replications. The obtained data of the research was expressed as the mean \pm standard deviation. The data was assessed by analysis of variance (ANOVA) and compared by Tukey comparison test ($p < 0.05$). The statistical analysis was carried out using Microsoft Office Excel 2016.

Results and Discussion

In this research, dehydration of honey was performed by two methods. One of the drying techniques was freeze-drying, which is widely used in pharmaceuticals due to its ability to preserve bioactive compounds (Nascimento *et al.*, 2015). Another drying method, which was used to obtain dehydrated honey, was spray-drying. Spray-drying is one of the most common techniques to obtain honey-rich powders (Samborska, Gajek, & Kamińska-Dwórznička, 2015). In this study, the drying experiments of 20% honey solutions with maltodextrin resulted in honey-rich powders. The moisture content in the honey powder,

which was obtained by freeze-drying, was 5.3% and in the honey powder, which was obtained by spray-drying, was 4.8%. Maltodextrin is mainly used for drying sugar and acid rich food products (Umesh Hebbar, Rastogi, & Subramanian, 2008). It has a high molecular weight, which helps to increase the glass temperature of drying particles and reduces hygroscopicity. Nurhardi and co-workers also used maltodextrin (1:1) in their study of obtaining honey powder by spray-drying and vacuum drying methods. The moisture content in the spray-dried honey powder was 2.3%, but in the vacuum-dried powder it was 1.0% (Nurhadi *et al.*, 2012). Sramek and co-authors obtained honey-rich powder by the freeze-drying method. In this study, honey was mixed with glucose syrup to prepare the powder. The moisture content in the final product was 3.1% (Sramek *et al.*, 2016). Our results and other researchers' studies showed that moisture content could be reduced by choosing different drying aids and changing the ratio of honey and drying aids in solutions.

α -amylase activity was detected to evaluate the quality of obtained powders. The value of diastase number in both dehydrated honey samples was not lower than 8 (Figure 1).

The lowest enzymatic activity was presented in the spray-dried honey, where the value of diastase number was 8.3 \pm 0.2. During the spray-drying, the water of the solution was removed, which resulted in degradation of molecules and loss of enzymatic activity. Samborska and co-workers (Samborska *et*

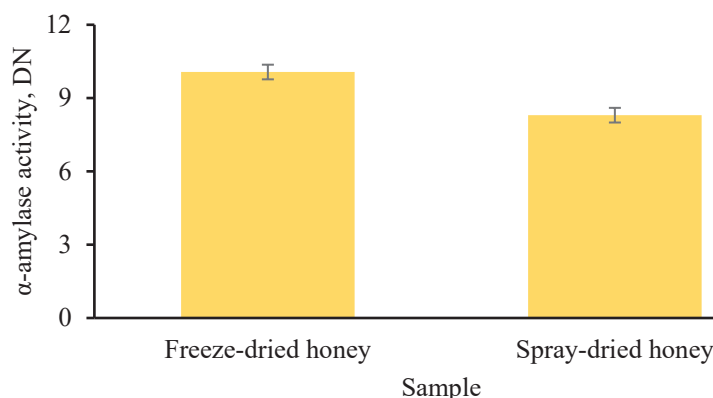


Figure 1. α -amylase activity in freeze-dried and spray-dried honey samples.

Table 2

Content of HMF, fructose, and glucose in dehydrated honey

Sample	HMF, mg kg ⁻¹	Fructose, g 100 g ⁻¹	Glucose, g 100 g ⁻¹
Freeze-dried honey	28.1 \pm 0.2	16.7 \pm 0.3	9.2 \pm 0.4
Spray-dried honey	36.5 \pm 0.3	16.5 \pm 0.2	9.5 \pm 0.5

al., 2017b), who obtained honey powder using spray drying method, reported that α -amylase (diastase) activity in their product was 10.9 ± 0.2 DN. They also pointed out that the enzymatic activity in the honey powder was lower than it was in fresh honey (14.4 ± 0.2 DN). Freeze-dried honey sample showed higher α -amylase activity than the spray-dried sample. The value of α -amylase activity in the freeze-dried sample was 10.0 ± 0.3 DN. The obtained results on α -amylase activity showed that freeze-drying is more gentle drying technique than spray-drying. Unfortunately, there are lack of literature data on α -amylase activity changes during the freeze-drying process that could be used to compare our obtained results. The concentration of hydroxymethylfurfural (HMF) was detected in obtained dehydrated honey samples (Table 2).

The powder, which was produced using a spray dryer, had higher concentration of HMF than the powder that was obtained by freeze-drying. The concentration of HMF in the spray-dried honey was 36.5 ± 0.3 mg kg⁻¹ and in the freeze-dried honey it was 28.1 ± 0.2 mg kg⁻¹. The obtained results showed that the used drying method significantly ($p < 0.05$) impacts the concentration of HMF in the product. Hydroxymethylfurfural is formed during dehydration of monosaccharides (fructose and glucose) and/or during the Maillard reaction (Kowalski & Lukasiewicz, 2017; Shapla *et al.*, 2018). The formation of hydroxymethylfurfural also depends on the factors such as pH, free acidity, temperature etc (Kowalski *et al.*, 2013). As high temperatures (inlet air temperature: 180 °C; outlet air temperature: 80 °C) were used during the spray-drying process, it caused the increase of the content of hydroxymethylfurfural in the final product. The high temperature in the spray drying process and low pH of multifloral honey (pH=3.66±0.01) were the

catalysts of the formation of hydroxymethylfurfural (Shapla *et al.*, 2018). The statistical analysis of the obtained data showed that the chosen drying methods did not impact the content of fructose ($p > 0.05$) and glucose ($p > 0.05$) in the honey powder.

The further studies should be focused on the obtaining of honey powder by freeze-drying. Freeze-drying is a gentle drying method, which preserves bioactive compounds and allows to produce high-quality food products (Karam *et al.*, 2016). The method should be modified to improve the quality of honey powders. The method could be used as an alternative method to obtain high quality honey-rich powder in the food industry. The obtained results showed that the used drying method impacts two important quality parameters α -amylase activity and the concentration of hydroxymethylfurfural in the honey-rich powder.

Conclusions

The obtained results showed that freeze-drying and spray drying can be used to obtain honey-rich powders. α -amylase activity in both powders decreased during the drying process. Freeze-dried honey powder had better quality as α -amylase activity was higher and the content of hydroxymethylfurfural was lower than spray-dried honey powder.

Acknowledgements

This research was supported by the Latvia University of Life Sciences and Technologies' project 'Strengthening Research Capacity in the Latvia University of Life Sciences and Technologies'. Project No. 3.2-10/2019/LLU/140. The authors would like to thank to Dr. sc. ing. Igors Šepeļevs for sharing his knowledge and experience during the spray drying experiments.

References

- Bhandari, B.R., Datta, N., & Howes, T. (1997). Problems associated with spray drying of sugar-rich foods. *Drying Technology*, 15(2), 671–684. DOI: 10.1080/07373939708917253.
- Cui, Z.W., Sun, L.J., Chen, W., & Sun, D.W. (2008). Preparation of dry honey by microwave-vacuum drying. *Journal of Food Engineering*, 84(4), 582–590. DOI: 10.1016/j.jfoodeng.2007.06.027.
- The Council of the European Union. (2002). *Directive relating to honey 2001/110/EC*.
- Geana, E.I., & Ciucure, C.T. (2020). Establishing authenticity of honey via comprehensive Romanian honey analysis. *Food Chemistry*, 306(September 2019), 125595. DOI: 10.1016/j.foodchem.2019.125595.
- Jedlińska, A., Samborska, K., Wieczorek, A., Wiktor, A., Ostrowska-Ligęza, E., Jamróz, W., ... Witrowa-Rajchert, D. (2019). The application of dehumidified air in rapeseed and honeydew honey spray drying - Process performance and powders properties considerations. *Journal of Food Engineering*, 245(July 2018), 80–87. DOI: 10.1016/j.jfoodeng.2018.10.017.
- Karam, M.C., Petit, J., Zimmer, D., Baudelaire Djantou, E., & Scher, J. (2016). Effects of drying and grinding in production of fruit and vegetable powders: A review. *Journal of Food Engineering*, 188, 32–49. DOI: 10.1016/j.jfoodeng.2016.05.001.
- Kılınc, M., & Demir, K.M. (2017). The Facilities of Spray Dried Honey Powder Use As a Substitute for Sugar in Cookie Production. *Journal of Food and Health Science*, 3(2), 67–74. DOI: 10.3153/JFHS17009.

- Kowalski, S., & Lukasiewicz, M. (2017). Diastase and Invertase Activity Changes and 5-Hydroxymethyl-2-Furfural Formation in Honeys Under Influence of Microwave Irradiation. *Journal of Food Process Engineering*, 40(2). DOI: 10.1111/jfpe.12410.
- Kowalski, S., Lukasiewicz, M., Bednarczyk, S., & Panus, M. (2012). Diastase number changes during thermal and microwave processing of honey. *Czech Journal of Food Sciences*, 30(1), 21–26. DOI: 10.17221/123/2010-cjfs.
- Kowalski, S., Lukasiewicz, M., Duda-Chodak, A., & Zięć, G. (2013). 5-hydroxymethyl-2-furfural (HMF) – heat-induced formation, occurrence in food and biotransformation – A review. *Polish Journal of Food and Nutrition Sciences*, 63(4), 207–225. DOI: 10.2478/v10222-012-0082-4.
- Muzaffar, K. (2015). Stickiness Problem Associated with Spray Drying of Sugar and Acid Rich Foods: A Mini Review. *Journal of Nutrition & Food Sciences*, s12(August), 10–13. DOI: 10.4172/2155-9600.s12-003.
- Nascimento, A.P., Moraes, L.A.R., Ferreira, N.U., De Padua Moreno, G., Uahib, F.G.M., Barizon, E.A., & Berretta, A.A. (2015). The lyophilization process maintains the chemical and biological characteristics of royal jelly. *Evidence-Based Complementary and Alternative Medicine*, 2015, 8–12. DOI: 10.1155/2015/825068.
- Nurhadi, B., Andoyo, R., Mahani, & Indiarso, R. (2012). Study the properties of honey powder produced from spray drying and vacuum drying method. *International Food Research Journal*, 19(3), 907–912. DOI: 10.1093/ijf/19.3.907.
- Nurhadi, B., & Roos, Y.H. (2016). Dynamic water sorption for the study of amorphous content of vacuum-dried honey powder. *Powder Technology*, 301, 981–988. DOI: 10.1016/j.powtec.2016.07.055.
- Pasias, I.N., Kiriakou, I.K., & Proestos, C. (2017). HMF and diastase activity in honeys: A fully validated approach and a chemometric analysis for identification of honey freshness and adulteration. *Food Chemistry*, 229, 425–431. DOI: 10.1016/j.foodchem.2017.02.084.
- Ribeiro, G.P., Villas-Bôas, J.K., Spinosa, W.A., & Prudencio, S.H. (2018). Influence of freezing, pasteurization and maturation on Tiúba honey quality. *LWT – Food Science and Technology*, 90(July 2017), 607–612. DOI: 10.1016/j.lwt.2017.12.072.
- Sakač, M.B., Jovanov, P.T., Marić, A.Z., Pezo, L.L., Kevrešan, Ž.S., Novaković, A.R., & Nedeljković, N.M. (2018). Physicochemical properties and mineral content of honey samples from Vojvodina (Republic of Serbia). *Food Chemistry*, 276, 15–21. DOI: 10.1016/j.foodchem.2018.09.149.
- Samborska, K. (2019). Powdered honey – drying methods and parameters, types of carriers and drying aids, physicochemical properties and storage stability. *Trends in Food Science and Technology*, 88(May 2017), 133–142. DOI: 10.1016/j.tifs.2019.03.019.
- Samborska, K., Gajek, P., & Kamińska-Dwórznička, A. (2015). Spray drying of honey: The effect of drying agents on powder properties. *Polish Journal of Food and Nutrition Sciences*, 65(2), 109–118. DOI: 10.2478/pjfn-2013-0012.
- Samborska, K., Sokołowska, P., & Szulc, K. (2017a). Diafiltration and agglomeration as methods to improve the properties of honey powder obtained by spray drying. *Innovative Food Science and Emerging Technologies*, 39, 33–41. DOI: 10.1016/j.ifset.2016.10.002.
- Samborska, K., Wasilewska, A., Gondek, E., Jakubczyk, E., & Kamińska-Dwórznička, A. (2017b). Diastase Activity Retention and Physical Properties of Honey/Arabic Gum Mixtures after Spray Drying and Storage. In *International Journal of Food Engineering* (Vol. 13), Walter de Gruyter GmbH. DOI: 10.1515/ijfe-2016-0320.
- Schade, J.E., Marsh, G.L., & Eckert, J.E. (1958). Diastase activity and hydroxy-methyl-furfural in honey and their usefulness in detecting heat alteration. *Journal of Food Science*, 23(5), 446–463. DOI: 10.1111/j.1365-2621.1958.tb17592.x.
- Shapla, U.M., Solayman, M., Alam, N., Khalil, M.I., & Gan, S.H. (2018, December 4). 5-Hydroxymethylfurfural (HMF) levels in honey and other food products: effects on bees and human health. *Chemistry Central Journal*. DOI: 10.1186/s13065-018-0408-3.
- Shi, Q., Fang, Z., & Bhandari, B. (2013). Effect of Addition of Whey Protein Isolate on Spray-Drying Behavior of Honey with Maltodextrin as a Carrier Material. *Drying Technology*, 31(13–14), 1681–1692. DOI: 10.1080/07373937.2013.783593.
- Sramek, M., Woerz, B., Horn, H., Weiss, J., & Kohlus, R. (2016). Preparation of High-Grade Powders from Honey–Glucose Syrup Formulations by Vacuum Foam-Drying Method. *Journal of Food Processing and Preservation*, 40(4), 790–797. DOI: 10.1111/jfpp.12660.
- Subramanian, R., Hebbar, H.U., & Rastogi, N.K. (2007). Processing of honey: A review. *International Journal of Food Properties*, 10(1), 127–143. DOI: 10.1080/10942910600981708.

- Tappi, S., Laghi, L., Dettori, A., Piana, L., Ragni, L., & Rocculi, P. (2019). Investigation of water state during induced crystallization of honey. *Food Chemistry*, 294(January), 260–266. DOI: 10.1016/j.foodchem.2019.05.047.
- Tosi, E.A., Ré, E., Lucero, H., & Bulacio, L. (2004). Effect of honey high-temperature short-time heating on parameters related to quality, crystallisation phenomena and fungal inhibition. *LWT – Food Science and Technology*, 37(6), 669–678. DOI: 10.1016/j.lwt.2004.02.005.
- Umesh Hebbar, H., Rastogi, N.K., & Subramanian, R. (2008). Properties of Dried and Intermediate Moisture Honey Products: A Review. *International Journal of Food Properties*, 11(4), 804–819. DOI: 10.1080/10942910701624736.

ASSESSMENT OF INGREDIENTS AND NUTRITIONAL VALUE OF VEGAN PRODUCTS IN LATVIAN MARKET

*Alla Mariseva, Ilze Beitane

Latvia University of Life Sciences and Technologies, Latvia

*Corresponding author's email: alla_marisheva@inbox.lv

Abstract

Nowadays, veganism is becoming increasingly popular, because health concerns are usually the primary reason why people turn to vegan diet. The aim of the study was to identify the supply of vegan products on the Latvian market by analysing the ingredients used in the production of the products, nutritional and energy value of vegan products. 192 vegan products made in 20 different countries and available in online stores that offer their goods on the Latvian market were analysed. The research was carried out from January to March 2020. Information on the country of origin, ingredients, nutritional and energy value of the products was taken from product labels. The majority of the vegan products in Latvian online stores comes from Germany. The most important ingredient in the production in product groups such as meat substitutes and dairy alternatives is soya (*Glycine max.*), which provides high protein content. The vegan products could not be characterized as low in fat, as the average fat content in the various product groups ranged from 7.9 ± 1.7 to 19.7 ± 3.3 g 100 g⁻¹ of product, except beverages. The average energy values for all product groups varied between 210.7 kJ 100 mL⁻¹ for beverages and 1226.0 kJ 100 g⁻¹ for snacks. There would be a need for everyday vegan products in the Latvian market, as most of the products are snacks at the moment, and legumes should be used as ingredient in the production of new vegan products with increased nutritional value.

Key words: vegan products, ingredients, nutritional and energetic value.

Introduction

Nowadays, veganism is becoming increasingly popular, because it has been promoted by the Internet, newspapers, magazines and other media. This phenomenon has also been attracting the attention of the scientific community as it seemingly solves many health and environment related problems as well as poses many questions as to its benefits and faults. As veganism is not just a dietary pattern that excludes any animal-based foods (meat, fish, dairy products, eggs), it touches many other aspects of its practitioners' lives. A choice of becoming vegan can be motivated by many reasons. For example, this may be due to religious views or ethical concerns, environmentalism, family and cultural traditions, or it may be dictated by the practitioner's health condition or financial status, etc. (Perez, Moreira, & Acevedo, 2015). Nevertheless, health concerns are usually the primary reason why people turn to vegan diet. For example, veganism can have a therapeutic or preventive effect on some chronic diseases. A number of studies have found that vegans have the lowest body mass index (BMI) compared with omnivores and vegetarians (Spencer *et al.*, 2003). Lower BMI for vegans is explained by reduced intake of fat, especially trans- and saturated fatty acids. However, they have no lack of polyunsaturated fatty acids, e.g. linoleic and α -linolenic acids, which are crucial for the human body. All the above mentioned values are connected with decreased insulin resistance and increased insulin secretion (Kahleova *et al.*, 2019); thus, preventing the risk of developing type 2 diabetes (Petti *et al.*, 2017). In addition, recent findings have reported that a vegetarian/vegan diet significantly lowers the risk of some cancers, cerebrovascular diseases as well as circulatory and

ischemic heart diseases (Petti *et al.*, 2017). In studies conducted in many countries, it has been discovered that the vegan diet contains less energy, what is often associated with a lower cardiometabolic risk – better low-density lipoprotein (LDL) cholesterol, fasting blood glucose and triglycerides, BMI and lipid variables (Dinu *et al.*, 2017; Benatar & Stewart, 2018; Lopez *et al.*, 2019). A diet that excludes animal-based products no doubt impacts the bone health of its practitioners, the nature of this impact is yet to be discovered for some age groups. It has now been demonstrated that young adults are most likely to benefit from such a diet (Knurick *et al.*, 2015). A study conducted in Asia in 2012 has given no confirmation of the fact that vegans were more prone to bone loss than omnivores, notwithstanding the higher rates in vitamin D deficiency and lower dietary calcium intakes in the former (Ho-Pham *et al.*, 2012). From the gut microflora perspective, vegans present a unique profile where the presence of pathobionts seems to be reduced and the protective organisms seem to be of larger abundance. This leads to reduced levels of inflammation and can in turn enhance the protective health effect of the gut. There would need to be further research on the effect of such a diet in long-term and short-term (Glick-Bauer & Yeh, 2014).

The Federal Commission for Nutrition (FCN) in Switzerland following an examination of the data of many nutritional studies reports that a well-balanced vegan diet implies an appropriate choice of supplements with micronutrients and vitamins in order to avoid developing any serious deficiencies (Federal Commission for Nutrition, 2018). It has been well documented that vegetarian and vegan diets provide low amounts of calcium, vitamin B₁₂

and D vitamin (Schüpbach *et al.*, 2017) as well as n-3 Polyunsaturated Fatty Acids (PUFAs) and zinc, iron (Fe^{2+} in particular), iodine (Petti *et al.*, 2017) and vitamin A (Key, Appleby, & Rosell, 2006). On the other hand, these dietary patterns are recognized as being rich sources of magnesium, vitamin C and folic acid, vitamin B₁ and B₆ (Schüpbach *et al.*, 2017), vitamin E, n-6 PUFA, fibre and carotenoids (Key, Appleby, & Rosell, 2006; Petti *et al.*, 2017), as well as carbohydrates (Key, Appleby, & Rosell, 2006).

In Latvia, vegan lifestyle is gaining in popularity. Reports from supermarket Maxima Latvia have shown a 150% growth in demand for vegan products in the year 2018 comparing to the year before (Savitska, 2019). According to the supermarket Rimi Latvia statistics, approximately 1% of their customers purchase vegan products on regular basis. Both supermarket chains have separate shelves in their stores dedicated solely to vegan products. Among them there is a variety of meat substitutes, cheese alternatives, sweets. Meat alternatives are regarded as a help to people in transition, if they find it difficult in the beginning to radically abstain from all varieties of meat products. They make the vegan lifestyle seem less restrictive (Twine, 2018). Consequently, major local food companies, such as 'Nuteko', 'Skriveru majas saldejums', 'Spilva', 'Valmiermuiza', 'Terapija', etc. are interested in developing ranges of vegan products that are being presented at an annual Latvian Vegan festival.

In 2007, the Ministry of Health of the Republic of Latvia has confirmed that the vegetarian and vegan diets are healthy and the plant-based diet can provide the necessary amount of nutrients to the human body (Ministry of Health, 2007). Ten years later, the Ministry of Health of the Republic of Latvia has released Healthy diet recommendations for vegetarians where vegans were mentioned as a subgroup (Ministry of Health, 2017).

The increased interest in vegan products is causing the growth of demand for these products on the market and, respectively, more and more companies are interested in producing these goods. The aim of the study was to identify the supply of vegan products on the Latvian market by analysing the ingredients used in the production of the products, nutritional and energy value of vegan products.

Materials and Methods

Within the framework of the study, 17 online stores were identified by analysing their offer. The stores that did not have a separate vegan and vegetarian section were immediately excluded from the research. As a next step, all stores that did not provide any information on the country of origin of their products, as well as the nutritional and energetic value, and complete

ingredient lists, were excluded from the study. In total, only 4 online stores met the criteria for the study. Vegan products with more than one ingredient were selected for the study. In total, 192 vegan products made in 20 different countries and available in online stores, that offer their goods on the Latvian market were analysed. The research was carried out from January to March 2020. Information on the country of origin, ingredients, nutritional and energy value of the products was taken from product labels, descriptions in the online store. Product nutrition information included the amount of protein, fat, saturated fat, carbohydrates, sugars and sodium. All the analysed products were divided into seven groups: beverages, dairy alternatives, meat substitutes, flour products, snacks, sweets or desserts and other. The 'beverage' group contains products like rice, oatmeal, almond, coconut, soya and other type of beverages. 'Dairy alternatives' are mainly tofu and cheese alternatives. Vegan seitan and soya sausages, steak alternatives, soya patties and chops constitute the 'meat substitutes' group. Under the 'flour product' group such products as cakes, vegan bread, pizzas and lasagne are found. The 'snacks' group includes humus, pâtés and creams. Ice creams and berry flavoured desserts were placed in the 'sweets, desserts' group, whereas the remainder of products, for example, vegetable sauces, syrups, products made from vegetable fat were placed in the 'other' product group. The 'others' food group was excluded from the nutritional and energetic value analysis due to the large differences between the products. The data was processed in Microsoft Office Excel (Version: 14.0.7188.5002 (64-bit), calculating the mean value, standard error of the mean (SEM), minimum and maximum value for the nutritional and energetic value of the products.

Results and Discussion

The majority of the vegan products in Latvian online stores comes from Germany providing 33% of the total vegan product offering (Figure 1). According to the market research company 'Mintel', in the last few years, Germany has been the leading vegan food producer in the world. In the time from 2013 to 2018, the number of high-quality vegan products in Germany has increased by 240% (Domke, 2018; Mintel, 2018). The main target group for these products are flexitarians who do not altogether exclude animal products from their diet, but rather tend to include more vegan foods by reducing the consumption of animal products. Flexitarianism and ethical consumerism, among younger consumers in particular, have been found to be the key reasons of the vegan product growth in Germany (Coyné, 2018). About 35% of Germans say they understand the benefits of vegetarianism and over 60% of the

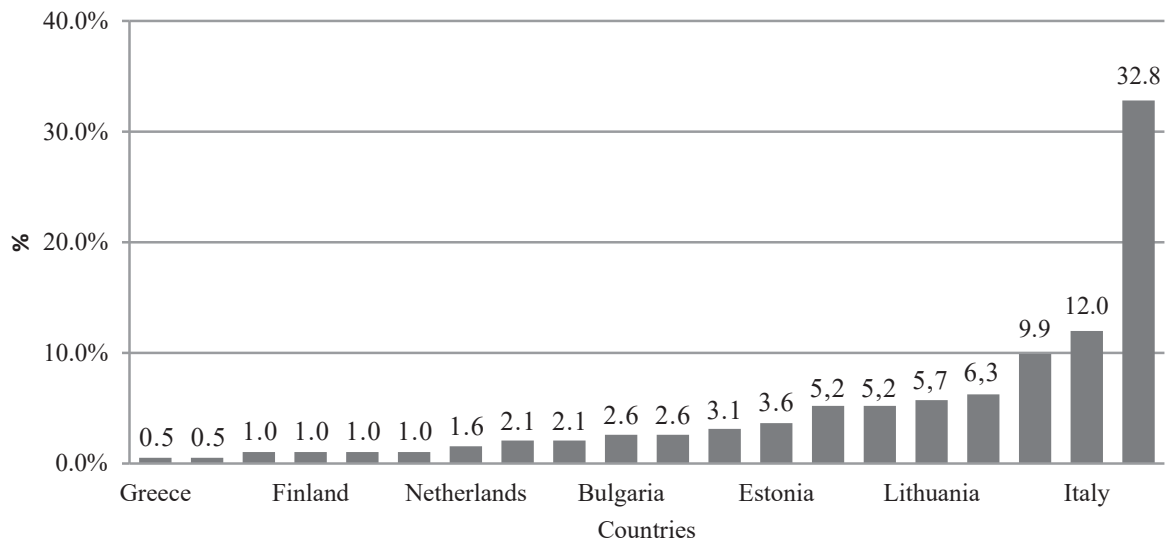


Figure 1. Proportion (%) of vegan products by country of origin available in online stores.

population is consciously trying to consume less meat. German vegans are also known for their preference of natural, unprocessed and whole foods preferring products labelled ‘no additives’, ‘organic’, ‘allergen-free’ and ‘gluten-free’ (U.S. Department of Agriculture Foreign Agricultural Service, 2020).

As the next largest producer of vegan products on the Latvian market is Italy (12.0%), followed by the Czech Republic (9.9%), Belgium (6.3%), Lithuania (5.7%) and then Latvia and the UK with 5.2%.

Analysing a vegan product by groups vegan snacks provided the largest part of the offer (28%) followed by meat substitutes and dairy alternatives (Figure 2). Generally, vegan products cover all product groups. However, there are wide-ranging opportunities for producers to develop new vegan products that could

provide a wholesome meal, considering that snacks are like a between meal not a daily diet.

The five most commonly used ingredients for vegan products were soya (*Glycine max*), starch, wheat (*Triticum*), pulses (*Fabaceae*), and oats (*Avena sativa*), where the main ingredient was soya, which was used in 48.4% of the vegan products. It was used in the production of meat substitutes like sausages and steaks; dairy alternatives like cheese alternatives; snacks; sweets, desserts; flour products and beverages (Figure 3).

Soybean’s nutritional value makes them a potential replacement for dairy products, meat and fish. It is a source of high biological value protein, amino acids (tryptophan, lysine etc.), carbohydrates, fat as well as vitamins, minerals, dietary fibre, omega-3 fatty acids,

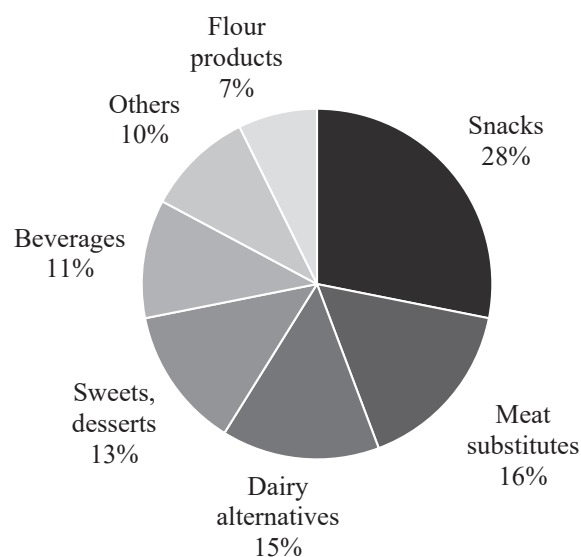


Figure 2. Vegan products by product groups available in online stores, %.

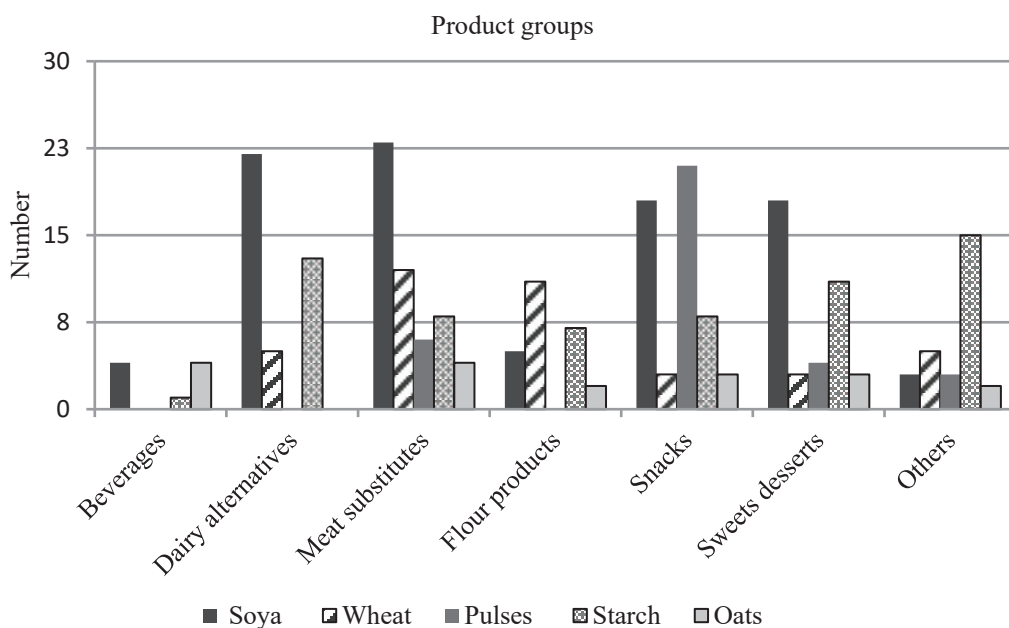


Figure 3. Most used ingredients in analysed vegan products available in online stores.

etc. All this, combined with a very reasonable price, makes processed soybean seeds a worthy alternative to animal protein sources (Sharma, Gupta, & Joshi, 2015).

The second most commonly used ingredient was modified potato and corn starch (32.8%) used in all product groups. The presence of starch enhances the energy value but not the nutritional value of the product. Manufacturers might consider other alternatives to starch using legume flour to increase the nutritional value of the products. Pulses (*Fabaceae*) were used as the main ingredient only in 17.7% of products, where most of them were snacks. A study on legume consumption in Latvia in 2014 showed that legumes, thanks to their high protein and other valuable nutrients, can significantly improve the diet of people who do not consume meat (Kirse & Karklina, 2014).

After having analysed all the product labels, it should be noted that in 78% of the analysed products con-

tain stabilizers and emulsifiers. These stabilizers and emulsifiers are mainly modified corn and potato starch, tapioca, as well as stabilizers like E 418 gellan gum, E 410 locust bean gum, E 412 guar gum, E 407 carrageenans and E 415 xanthan gum. In addition, thickeners like E 461 methylcellulose, E 471 mono- and diglycerides of fatty acids, E 472e mono- and diacetyl tartaric acid esters of mono- and diglycerides, and E 482 calcium stearoyl lactate were used.

Within the framework of the study the nutritional and energy values of each product group were analysed: beverages and dairy alternatives (Table 2); flour products and snacks (Table 3); meat substitutes and sweets and desserts (Table 4).

In the vegan beverages group, 81.8% of products contained up to 1.5 g of fat per 100 mL and according to the Regulation (EU) No 1924/2006 (European Parliament & Council, 2006) on nutrition and health claims made on foods complied with the nutrition

Table 2

Nutritional and energy value of beverages and dairy alternatives, per 100 mL or 100 g

	Beverages, n=22			Dairy alternatives, n=28		
	Average ± SEM	Min	Max	Average ± SEM	Min	Max
Energy, kJ	210.7±44.8	54.0	594.0	1029.3±194.6	209.0	3495.0
Protein, g	1.1±0.2	0.1	4.0	9.7±1.4	0	21.5
Fat, g	1.3±0.1	0.2	2.3	19.7±3.3	2.3	93.7
Saturated fat, g	0.5±0.2	0	3.3	7.5±2.0	0	40.1
Carbohydrates, g	5.8±1.0	0	13.0	7.6±1.5	0.2	25.5
Sugars, g	3.3±0.5	0	28.3	1.2±0.4	0	7.1
Sodium, g	0.1±0.0	0	0.2	1.0±0.2	0	2.3

Table 3

Nutritional and energetic value of flour products and snacks per 100 g

	Flour products, n=14			Snacks, n=54		
	Average ±SEM	Min	Max	Average ±SEM	Min	Max
Energy, kJ	1116.6±102.1	442.0	1778.0	1226.0±119.5	400.0	7151.0
Protein, g	8.0±1.4	2.9	21.8	8.9±1.2	1.1	42.6
Fat, g	9.8±1.4	2.0	18.0	19.3±1.2	1.2	35.0
Saturated fat, g	3.6±1.1	0	11.5	3.1±0.4	0	14.0
Carbohydrates, g	36.6±4.4	3.3	61.0	13.2±1.7	1.5	66.0
Sugars, g	6.7±2.5	0	27.1	2.5±0.3	0	9.0
Sodium, g	1.1±0.2	0	3.4	1.4±0.1	0	7.0

Table 4

Nutritional and energy value of meat substitutes and sweets and desserts per 100 g

	Meat substitutes, n=30			Sweets, desserts, n=25		
	Average ± SEM	Min	Max	Average ± SEM	Min	Max
Energy, kJ	956.6±74.3	212.0	1878.0	733.0±88.1	305.0	1545.0
Protein, g	22.4±2.4	4.0	52.0	4.0±0.6	0.9	12.0
Fat, g	11.3±1.3	0.4	33.0	7.9±1.7	1.5	27.6
Saturated fat, g	2.2±0.8	0	22.0	4.7±1.3	0.2	23.0
Carbohydrates, g	7.5±0.8	2.1	20.0	19.0±1.5	9.4	32.0
Sugars, g	1.9±0.3	0	7.0	13.1±1.5	0	26.0
Sodium, g	1.2±0.1	0	2.8	0.2±0.0	0	0.8

claim 'low in fat'. For 77.3% of products the sum of saturated fatty acids did not exceed 0.75 g 100 mL⁻¹, and these products could be labelled 'low in saturated fat'. The highest fat content was in the group of dairy alternatives (19.7 g 100 g⁻¹) and snacks (19.3 g 100 g⁻¹), whereas the highest amount of saturated fat was in the group of dairy alternatives (7.5 g 100 g⁻¹). In general, a vegan diet is characterized by low fat content, especially unsaturated fat. The study of Kahleova *et al.* (2019) showed that a 16-week vegan diet helped to reduce fat intake from 36.1% to 17.5% of total energy, reducing total fat by 48.9 g (from 77.7 to 28.8 g). In addition, the fat mass of the participants, especially the internal fat, was reduced. With the exception of vegan beverages, the products selected in this study could not be characterized as low in fat, as the average fat content in the various product groups ranged from 7.9±1.7 to 19.7±3.3 g 100 g⁻¹ of product.

In the meat substitute group, the energy value was 956.6±74.3 kJ 100 g⁻¹ with a protein content of 22.4±2.4 g 100 g⁻¹, which was the highest amount among all groups. The main sources of protein in the products were soya and legumes. The comparison of meat substitutes with poultry meat, which has an average energy value of 1278.2–1350.6 kJ 100 g⁻¹ with

a protein content of 22–24 g 100 g⁻¹ (Neacșu *et al.*, 2016), showed that the protein content is equivalent while the energy value is lower, which is associated with lower fat content in meat substitutes. Although research showed that the amount of protein in the total energy intake for vegans constituted 13%, whereas it was 17.5% for omnivores (Mariotti & Gardner, 2019). However, there was no protein deficiency, except for a group of vegetarians, who, for some reason, excluded protein-rich plants like nuts, seeds, pulses, etc. from their diet.

It has been reported in the literature that meat substitutes were high in sodium, which is often an important factor in the development of many diseases (Curtain & Grafenauer, 2019). This statement was confirmed in this study as meat substitutes had an average salt value of 1.2±0.1 g 100 g⁻¹. However, the highest salt content was determined in snacks where the average value was 1.4±0.1 g 100 g⁻¹ of product, while the maximum value was 7.0 g salt per 100 g of product.

Analysing the sugar content of vegan products, it was concluded that the highest content was in the group of sweets, desserts, with an average value of 13.1±1.5 g 100 g⁻¹, followed by the group of flour products with 6.7±2.5 g 100 g⁻¹ and beverages –

6.5±1.8 g 100 g⁻¹. In other product groups, the average value of sugar content was less than 5 g 100 g⁻¹ of product, which should be considered as a positive aspect.

The energy value of vegan products depended on the type of product, where the lowest value was 54.39 kJ 100 mL⁻¹ of unsweetened almond-based dairy alternative to 3493.64 kJ 100 g⁻¹ of butter substitute. However, the average energy values for all product groups (210.7±44.8 kJ 100 mL⁻¹ for beverages – 1226.0±119.5 kJ 100 g⁻¹ for snacks) supported the statements in the literature that a vegan diet is lower in energy compared to omnivores (Dinu *et al.*, 2017; Benatar & Stewart, 2018).

Conclusions

The study showed that vegan product offerings are diverse, covering different product groups but could be broader, offering more choice for consumers. Currently, Germany is the largest producer of vegan products

in the world and in Europe, providing the largest supply of products also in Latvia. The most important ingredient in the production of vegan products is soya (*Glycine max*), which provided sufficient protein content in product groups such as meat substitutes and dairy alternatives. The nutritional and energy value of vegan products varied by product group. The average energy values for all product groups varied between 210.7 kJ 100 mL⁻¹ for beverages and 1226.0 kJ 100 g⁻¹ for snacks. For protein the average values ranged from 1.1 g 100 mL⁻¹ for beverages and 22.4 g 100 g⁻¹ for meat substitutes. Fat values varied between 1.3 g 100 mL⁻¹ for beverages and 19.7 g 100 g⁻¹ for dairy alternatives. Carbohydrates values ranged from 5.1 g 100 mL⁻¹ for beverages and 36.6 g 100 g⁻¹ for flour products.

The study showed that at the moment there is a lack of basic everyday vegan products, as almost one third of all the products are snacks, and that legumes should be used as ingredients in the production of new vegan products with increased nutritional value.

References

- Benatar, J.R., & Stewart, R.A.H. (2018). Cardio metabolic risk factors in vegans: A meta-analysis of observational studies [Electronic version]. *PLoS ONE*, 13(12), 1–23. DOI: 10.1371/journal.pone.0209086.
- Coyne, A. (2018). Germany vegan-food market deep-dive. part one – a perfect storm. Aroq – Just-Food.com (Global News). 10/27/2018. p1-1. 1p.
- Curtain, F., & Grafenauer, S. (2019). Plant-based meat substitutes in the flexitarian age: An audit of products on supermarket shelves. *Nutrients*, 11(11), 1–14. DOI: 10.3390/nu1112603.
- Dinu, M., Abbate, R., Gensini, G.F., Casini, A., & Sofi, F. (2017). Vegetarian, vegan diets and multiple health outcomes: A systematic review with meta-analysis of observational studies. *Critical Reviews in Food Science and Nutrition*, 57(17), 3640–3649. DOI: 10.1080/10408398.2016.1138447.
- Domke, F. (2018). Vegetarian and vegan products – labelling and definitions. *European Food and Feed Law Review: EFFL*, 13(2), 102–107.
- REGULATION (EU) No 1924/2006 OF THE EUROPEAN PARLIAMENT AND COUNCIL (2006) European Parliament and Council. Retrieved March 12, 2020, from <https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32006R1924&from=en>.
- Federal Commission for Nutrition. (2018). Expert report of the FCN. Retrieved March 12, 2020, from <https://www.eek.admin.ch/eek/en/home/pub/vor-und-nachteile-vegane-ernaehrung.html>.
- Glick-Bauer, M., & Yeh, M.C. (2014). The health advantage of a vegan diet: Exploring the gut microbiota connection. *Nutrients*, 6(11), 4822–4838. DOI: 10.3390/nu6114822.
- Ho-Pham, L.T., Vu, B.Q., Lai, T.Q., Nguyen, N.D., & Nguyen, T.V. (2012). Vegetarianism, bone loss, fracture and vitamin D: A longitudinal study in Asian vegans and non-vegans. *European Journal of Clinical Nutrition*, 66(1), 75–82. DOI: 10.1038/ejcn.2011.131.
- Kahleova, H., Hlozkova, A., Fleeman, R., Fletcher, K., Holubkov, R., & Barnard, N.D. (2019). Fat quantity and quality, as part of a low-fat vegan diet, are associated with changes in body composition, insulin resistance and insulin secretion. A 16-week randomized controlled trial. *Nutrients*, 11(3), 1–17. DOI: 10.3390/nu11030615.
- Key, T.J., Appleby, P.N., & Rosell, M.S. (2006). Health effects of vegetarian and vegan diets. *Proceedings of the Nutrition Society*, 65(1), 35–41. DOI: 10.1079/pns2005481.
- Kirse, A., & Karklina, D. (2014). Attitudes of Latvian adults to the consumption of pulses. In *Research for Rural Development*, 21–23. May 2014, Latvia University of Agriculture, Jelgava, 1, 130–137.
- Knurick, J.R., Johnston, C.S., Wherry, S.J., & Aguayo, I. (2015). Comparison of correlates of bone mineral density in individuals adhering to lacto-ovo, vegan, or omnivore diets: A cross-sectional investigation. *Nutrients*, 7(5), 3416–3426. DOI: 10.3390/nu7053416.
- Lopez, P.D., Cativo, E.H., Atlas, S.A., & Rosendorff, C. (2019). The Effect of Vegan Diets on Blood Pressure in Adults: A Meta-Analysis of Randomized Controlled Trials. *The American Journal of Medicine*, 132(7), 875-883.e7. DOI: 10.1016/j.amjmed.2019.01.044.

- Mariotti, F., & Gardner, C.D. (2019). Dietary protein and amino acids in vegetarian diets—A review. *Nutrients*, 11(11), 1–20. DOI: 10.3390/nu11112661.
- Ministry of Health (2007). Healthy eating tips for vegetarians. Retrieved March 12, 2020, from http://www.vm.gov.lv/images/userfiles/Tava%20veselibas/ves_uztura_ieteik_vegetariesi.pdf.
- Ministry of Health (2017). Veselīga uztura ieteikumi veģetāriešiem (Healthy diet recommendations for vegetarians). Retrieved March 12, 2020, from http://www.vm.gov.lv/images/userfiles/Tava_veselibas/ves_uztura_ieteik_vegetariesi.pdf. (in Latvian).
- Mintel. (2018, July). *Germany continues to dominate global vegan new product development*. Retrieved March 12, 2020, from <https://www.mintel.com/press-centre/food-and-drink/germany-continues-to-dominate-global-vegan-new-product-development>.
- Neacșu, M., Van, I., Popa, R., Popa, D., Vidu, L., & Dronca, D. (2016). Research on the Assessment of Biochemical Parameters of Poultry Meat under an Identical Level of Energy and Protein. *Scientific paper: Animal Science and Biotechnologies*, 49(1), 217–222. Retrieved March 12, 2020, from <http://web.b.ebscohost.com/ehost/pdfviewer/pdfviewer?vid=1&sid=5e216c39-e381-4380-a397-91c7d0bba8fc%40sessionmgr103>.
- Perez, I., Moreira, C., & Acevedo, C.R. (2015). Resistance to consumption and Veganism: A Study about Motivations, Values, and Feelings. *Revista Gestão & Tecnologia*, 15(2), 50–67. DOI: 10.20397/2177-6652/2015.v15i2.621.
- Petti, A., Palmieri, B., Vadalà, M., & Laurino, C. (2017). Vegetarianism and Veganism: Not Only Benefits but also Gaps. A review. *Progress in Nutrition*, 19(3), 229–242. DOI: 10.23751/pn.v19i3.5229.
- Savitska, J. (2019). Vegāniem produktu klāsts veikalos kļūst plašāks, bet – vai tas ir pietiekams? (The range of products for vegans in stores is becoming wider, but is that enough?). [Electronic version]. Retrieved March 12, 2020, from <https://www.lsm.lv/raksts/zinas/ekonomika/veganiem-produktu-klasts-veikalos-klust-plasaks-bet--vai-tas-ir-pietiekams.a325544/>. (in Latvian).
- Schüpbach, R., Wegmüller, R., Berguerand, C., Bui, M., & Herter-Aeberli, I. (2017). Micronutrient status and intake in omnivores, vegetarians and vegans in Switzerland [Electronic version]. *European Journal of Nutrition*, 56(1), 283–293. DOI: 10.1007/s00394-015-1079-7.
- Sharma, D., Gupta, R., & Joshi, I. (2013, November). Nutrient Analysis of Raw and Processed Soybean and Development of Value Added Soybean Noodles, 2014(1). Retrieved March 12, 2020, from <https://www.researchgate.net/publication/275270297>.
- Spencer, E.A., Appleby, P.N., Davey, G.K., & Key, T.J. (2003). Diet and body mass index in 38 000 EPIC-Oxford meat-eaters, fish-eaters, vegetarians and vegans. *International Journal of Obesity*, 27, 728–734. DOI: 10.1038/sj.ijo.0802300.
- Twine, R. (2018). Materially Constituting a Sustainable Food Transition: The Case of Vegan Eating Practice. *Sociology*, 52(1), 166–181. DOI: 10.1177/0038038517726647.
- U.S. Department of Agriculture Foreign Agricultural Service. (2020). *Germany is Leading a Vegalution – Vegan Revolution – in Europe*. Retrieved March 12, 2020, from https://apps.fas.usda.gov/newgainapi/api/Report/DownloadReportByFileName?fileName=Germany%20is%20Leading%20a%20Vegalution%20%20Vegan%20Revolution%20%20in%20Europe_Berlin_Germany_01-07-2020.

FIELD PEA *PISUM SATIVUM* L. AS A PERSPECTIVE INGREDIENT FOR VEGAN FOODS: A REVIEW

*Ieva Rasskazova, Asnate Kirse-Ozolina

Latvia University of Life Sciences and Technologies, Latvia

*Corresponding author's email: ievanr9@inbox.lv

Abstract

Dry seeds of peas (*Pisum sativum* L.) have long been used as a staple food and feed globally, and its nutritional, health and ecological benefits comply with growing demand for novel vegan foods intended for health and sustainability conscious individuals. The aim of this study was to review research findings and latest information on field pea usage as a functional ingredient in vegan foods. Monographic method was used to analyse field pea *Pisum sativum* L. usage as a diverse and multifunctional ingredient in vegan foods, covering latest available information on chemical composition of field pea and main food ingredients made from field pea, focusing on the varieties from which yellow split pea is produced; their impact on ready product's nutrition, sensory properties and application in food industry. Major types of novel vegan foods containing field peas available on market were named. Pea protein, starch and fibre have demonstrated functional properties in different food systems, including – emulsification, oil-in-water system stabilisation, texture modification, binding, gelation, foaming, and solubility. It is functionally possible and nutritionally and ecologically desirable to develop novel vegan foods intended as animal product alternatives with acceptable sensory properties.

Key words: plant protein, vegan food, functional properties, novel food, field pea.

Introduction

Peas, more specifically the yellow or green cotyledon varieties known as dry, smooth or field peas, are the naturally dried seeds of *Pisum sativum* L. and are grown around the world (in temperate and subtropical climate) (Dahl, Foster, & Tyler, 2012).

Cultural traditions have a strong influence on the type of peas grown and consumed in different regions and countries (Rawal *et al.*, 2019). Peas are also grown in Latvia – for human consumption, also animal feed and as a rotational crop for cereals to gain crop's higher energetic productivity (Kirse & Karklina, 2014; Osmane *et al.*, 2016). Pea landraces and varieties exhibit diversity of forms and growing types, adapted to diverse environments, cropping systems, and end-uses (as food, feed, or fodder) (Tayeh *et al.*, 2015). Latvian citizens usually consume green/ garden peas (*Pisum sativum* L.), chickpeas (*Cicer arietinum* L.), maple peas (*Pisum sativum* L. var. *arvense*) and yellow split peas (*Pisum sativum* L.) (Kirse & Karklina, 2014). The vast majority of the world's production of peas are yellow field peas, followed by green field peas and a few other types produced only in smaller quantities. World production of dry peas in 2018 was more than 13.5 million tonnes, the major producers being Canada, Russia and China; Latvia produced 22 500 tonnes of dry peas per year (FAOSTAT, 2020). Uniquely, when comparing with other legumes, in the developed countries dry pea production is driven by demand for animal feed and not for human consumption (Bansal & Bansal, 2019).

Peas being a legume crop have two aspects that distinguish them from most other food crops. Firstly, they are rich with macro and micronutrients: being a good source of protein (rich with essential amino acids as tryptophan and lysine), slowly digestible

carbohydrates, B group vitamins, minerals, dietary fibre (soluble and insoluble), phytosterols, α -linolenic acid; they also provide some amounts of squalene, tocopherols, polyphenols and triterpenic acids (Kalogeropoulos *et al.*, 2010; Rawal *et al.*, 2019; Roy, Boye, & Simpson, 2010).

Secondly, peas, like other plants of the *Leguminosae* family, take part in maintaining the environmental sustainability of agriculture with a process of biological nitrogen fixation. Pea crop in symbiosis with soil-borne rhizobia bacteria forms root nodules which absorb inert nitrogen from soil and air, and convert it into biologically useful ammonia, part of which is released into the soil. Consequently, the pulse crops do not need any additional nitrogen as fertilizer and the requirement of nitrogen fertilization in crops that follow in the cropping cycle is also reduced (Tayeh *et al.*, 2015).

Dry seeds of peas have long been used as a staple food and decreases symptoms of such with diet-related diseases as obesity, diabetes, heart diseases, also demonstrates positive influence in the prevention of various forms of cancer (Michaels, 2016). This effect has been directly linked to their chemical content and low glycaemic index, also with traditional usage as an alternative to animal protein in vegan and vegetarian diets (Rohn & van Griensven, 2015).

In general there is growing awareness of health and ecological benefits when choosing vegetarian, vegan or semi-vegetarian diet (Van Dooren *et al.*, 2014). The global market for plant-based products continues to grow, which creates demand for ingredients that comply with vegetarian and vegan dietary needs, especially more protein from ecologically sustainable sources. Global availability, nutritional, health and

ecological benefits makes field pea uniquely qualified as a source of new vegan foods.

The aim of this study was to review research findings and latest information on field pea's usage as a functional ingredient in vegan foods.

Materials and Methods

To analyse and summarise the latest information published in scientific journals on field pea's *Pisum sativum* L. composition, nutritional and health benefits, functional properties and functional ingredients acquired from its edible seeds for use in food industry, the monographic method was used. In order to compile information on some commercially available novel vegan foods made with pea ingredients, Internet resources were used.

Results and Discussion

Chemical composition, nutritional and health benefits of field pea

Approximate chemical content of pea *Pisum sativum* L. has recently been compiled by Dahl, Foster, & Tyler (2012). Whole pea seed contains: protein 21.2–32.9% of dry matter (DM), starch 36.9–49.0% DM, resistant starch 2.1–6.3% DM, amylose 20.7–33.7% of total starch, total dietary fibre 14–26% DM (including insoluble fibre 10–15% DM and soluble fibre 2–9% DM), soluble sugars 5.3–8.7% DM, total lipid 1.2–2.4% DM, ash 2.3–3.4% DM (Dahl, Foster, & Tyler, 2012). Field pea's chemical composition demonstrates which functional ingredient groups could be extracted from pea. Table 1 provides the overview of major functional properties associated with pea and specific pea fractions.

Peas are a valuable source of protein for human and animal diet. Pea protein content is influenced by pea seed maturity, environmental and genetic factors (Roy, Boye, & Simpson, 2010). It is approximately 22.5%

(18.59–26.37%) of dry matter in various pea varieties grown in Latvia (Osmane *et al.*, 2016), which makes it comparable with meat protein content. Although pea protein is not complete dietary protein (in comparison to meat, poultry, fish, dairy, eggs and soya (*Glycine max*) protein) with limiting amount of essential amino acids – methionine and tryptophan, it is good source of lysine (De Almeida Costa *et al.*, 2006). Krumina-Zemture, Beitane and Gramatina (2016) established that organic pea flour (Latvia) contains 19.30 g 100 g⁻¹ of total amino acids, from which approximately 35% (6.89 g 100 g⁻¹) was essential amino acids, from which 22% was lysine (1.58 g 100 g⁻¹). It is advised to include peas in plant based vegetarian and vegan diet together with other legumes and cereals to improve total dietary protein's adequacy (Kirse & Karklina, 2014).

Dry seeds of peas (and other pulses) rank below foods of animal origin but above other plant-based foods in terms of protein quality due to the presence of anti-nutritional factors such as phytates, protease inhibitors and lectins (Boye, Zare, & Pletch, 2010). *In vitro* digestibility of raw pea protein is reduced, although the digestibility of isolated pea protein has been reported to be higher than that of soybean and several other pulses (Osmane *et al.*, 2016; Yang *et al.*, 2012).

At the same time lectins and bioactive peptides have demonstrated bioactive properties: they exert anticancer, immunomodulatory properties and a variety of bioactivities *in vitro*, including angiotensin I-converting enzyme inhibitor activity with antihypertensive effect and antioxidant activity, accordingly (Roy, Boye, & Simpson, 2010).

Starch and fibre are other major components of pea seed DM (Dahl, Foster, & Tyler, 2012). In peas 18.2–23.8% of starch is rapidly digestible starch (RDS), slowly digestible starch (SDS) is 53.7–59.0% and resistant starch (RS) content is 8.1–12.6% (Hoover

Table 1

Major functional properties associated with pea and specific pea fractions in novel food systems

Pea fraction, % DM ^a	Functional properties in final product	Reference
Protein, 21.2–32.9%	– fat/ water binding, allowing adequate texture, emulsification, and gelation, – solubility, emulsifying stability and foaming properties, – good emulsification properties and emulsion stability upon heat and freeze-thaw treatments,	Geerts <i>et al.</i> , 2017, Lan <i>et al.</i> , 2019
Starch, 36.9–49.0%	– as a binder in food systems, – as texture modifying agents,	Pietrasik <i>et al.</i> , 2020
Dietary fibre 14–26%	– as a filler in food systems, – as texture modifying agents, – good stabilizing properties at acid condition,	Pietrasik <i>et al.</i> , 2020, Cheng <i>et al.</i> , 2018

^a – % DM – chemical component's amount in whole seed, % from dry matter (DM), information compiled by Dahl, Foster, & Tyler, (2012);

Table 2

Novel vegan foods made with field peas *Pisum sativum* L.

Product	Pea derived ingredient	Protein, g·100 ⁻¹ g (gPS ^a)	Producer (source) ^b
Cooked yellow split peas	split pea ^c	10 (13)	Kalogeropoulos <i>et al.</i> , (2010), Greece
100% pea protein powder	PPI	80 (20)	IronMaxx, Germany (IronMaxx.de)
		77 (23)	Prozis, Portugal (Prozis.com)
VEGANMASS – mass gainer powder	PPI, pea starch	39 (30)	Vegun Nutrition, USA (VegunNutrition.com)
MF burger	PPI	18 (20)	Beyond Meat, USA (BeyondMeat.com)
	rehydrated textured PPI, PF, pea fibre	14 (14)	©Iglo, Germany (Iglo.de)
	PP (with soya protein)	22 (22)	The Meatless Farm, UK (meatlessfarm.com)
MF meatballs	rehydrated textured PPI, PF, pea fibre	16 (16)	Birds Eye, Ireland (BirdsEye.ie)
MF minced meat	PPI	18 (20)	Beyond Meat, USA (BeyondMeat.com)
MF sausage preparation mix	PP (with chickpea PF)	No information	SIA Gardais, Latvia (Gardais.lv)
MF sausages	rehydrated PP, PF, pea fibre	16 (16)	Birds Eye, UK (BirdsEye.co.uk)
DA drink	PP	3 (8)	Qwrkee, UK (Qwrkee.com)
DA drink	PP	3 (8)	Ripple Foods, USA (RippleFoods.com)
DA drink	PPI	3 (8)	SIA “Nature Foods”, Latvia (Happea.com)
Creamy Yogurt Alternative, 150g	PP	4 (6)	Ripple Foods, USA (RippleFoods.com)
Pea & Pinto Bean Sticks, 100g	green PF	9 (3)	Off The Eaten Path Australia (OffTheEatenPathSnacks.com.au)
Probiotic Vegan Cheese Puffs 80g	PF	20 (4)	Qwrkee, UK (Qwrkee.com)
Protein bar, 75g	PP	29 (22)	Organic Food Bar, USA (OrganicFoodBar.com)

^a – g, PS – g per serving, according to producer’s information; ^b – web pages retrieved on March, 8, 2020; specific source information will be sent after individual request to author; ^c – boiled for 30 min and then left in colander for 5 min for drainage; MF – meat free, DA – dairy alternative, PP – pea protein, PPI – pea protein isolate, PF – pea flour.

et al., 2010). The properties of pea starch and fibre constituents make peas a low-glycaemic index food, which increases insulin response stability due to a decrease in blood glucose fluctuation after slower glucose release, which can help in the prevention and management of obesity, high blood cholesterol and type 2 diabetes (Dahl, Foster, & Tyler, 2012; Lu, Donner, & Liu, 2018). Major minerals in pea are K (1040 mg·100 g⁻¹ of dry, dehulled weight), P (390 mg·100 g⁻¹), Mg (100 mg·100 g⁻¹) and Ca (80 mg·100 g⁻¹). From trace minerals on average pea contains Fe (9.7 mg·100 g⁻¹), Se (4.2 mg·100 g⁻¹), Zn (4.1 mg·100 g⁻¹), Mo (1.2 mg·100 g⁻¹), Mn (1.1 mg·100 g⁻¹) and Cu (0.9 mg·100 g⁻¹). Pea contains folate in various amount from 23.7 µg·100 g⁻¹ to 101.0 µg·100 g⁻¹ (Dahl, Foster, & Tyler, 2012). Pea minerals bioavailability is poor due to high phytate

concentrations. Phytate degradation could make peas as a significant source of Ca, Zn and Fe (Dahl, Foster, & Tyler, 2012). Pea flour (Latvia) was observed to be a good source (in comparison to wheat) of vitamins B₁ and B₂ – 1.11 mg 100 g⁻¹ and 0.71 mg 100 g⁻¹, respectively (Beitane & Krumina-Zemture, 2017).

Pea application in food industry

In addition to traditional pea soups, casseroles, boiled and/or baked, roasted peas as staple food and humus made from canned, frozen or dried peas, there are many new vegan foods made with field pea or pea fractions recently launched on global food market. Some of these foods with their trade names, pea ingredient type and producer information are shown in Table 2.

Mostly dry pea flour (<65% protein, DM), protein concentrate (PPC, >65% protein, DM) or isolate (PPI,

>90% protein, DM) have been used as a source of protein and/ or for maintaining other functional and sensory properties in selected food (Boye, Zare, & Pletch, 2010).

Major novel vegan foods with pea ingredients could be categorised in such groups: meat product analogues (plant-based burgers, sausages, 'meat ball alternatives', 'minced meat alternatives' etc.), dairy product alternatives (drinks, yoghurt-like gels, cheese-like alternatives, and others, which usually have been recognised by using terms employed in dairy industry, but according to Regulation No 1308/2013 of the European Parliament and Council (Reg. 1308/2013, 2013) can't be labelled as such any more), food supplements (protein powders, emulsifiers), snacks (energy bars, extrudates), fortified cereal products (traditionally made with wheat – bread, pasta, crackers) and other.

Pea processing methods like soaking, steaming, thermal treatment, extrusion, fermentation, germination etc. affect pea chemical composition and can significantly improve pea protein digestibility and nutritional value, increase antioxidant activities (Boye, Zare, & Pletch, 2010; Singh *et al.*, 2017).

Most functionally researched, adapted and commercially used pea fraction is protein fraction (Table 1 and 2). Pea protein isolate main protein fractions are: salt-soluble globulin (60–80%) with the subunits of legumin (11S) and vicillin (7S) and water-soluble albumin (2S, 15–25%) (Shand *et al.*, 2007).

Pea protein flour processing techniques are: air classification, alkaline extraction/ isoelectric precipitation, acid extraction, water extraction, salt extraction (micellization) and ultrafiltration (Boye, Zare, & Pletch, 2010).

In fractionation process dried yellow peas are dehulled and ground (milled) to produce pea flour (PF). Then PF is hydrated, and the pea starch and fibre are extracted separately from protein fraction. By alkaline extraction followed by isoelectric precipitation the protein fraction is coagulated for further purification and, finally, carefully dried in a multi-stage spray dryer. This is so called wet milling process, which results in extracts with higher protein purity (>70%) (Boye, Zare, & Pletch, 2010; Yang *et al.*, 2012). Also, pea starch isolate, obtained by wet milling processing is generally of higher purity (Hoover *et al.*, 2010).

In dry milling fractionation process from PF through air classification process there are two separated fractions obtained: the coarser (heavier) low protein starch fraction and the lighter (finer) protein fraction. Air classification does not completely separate the protein from the starch granules and fibre, the purity of the protein fraction obtained using this process is approximately 38–65%, that is why wet extraction process, ultrafiltration or isoelectric

precipitation could follow (Boye, Zare, & Pletch, 2010; Hoover *et al.*, 2010). Air classification as dispersion/solubilization of the dehulled pea flour in water and concentration of the soluble protein after decantation of the insoluble residue (fibres and starch) followed by spray drying techniques are perceived as more sustainable process (with less use of water and chemicals) and have the advantage that protein retains its native state (Geerts *et al.*, 2017; Moreno *et al.*, 2020).

Manufacturing processes used to produce the protein extracts impact to different extent their functional properties (Boye, Zare, & Pletch, 2010). With comparable nutritional and functional properties that of soya pea protein has replaced soya protein in many foods because it is perceived as being non-allergenic or non-GMO in comparison with soya (Messina & Venter, 2020).

Though, when processed under the same conditions, pea protein isolate forms a weaker and less elastic gel than soy protein isolate (Shand *et al.*, 2007). Shand *et al.* (2007) and Sun & Arntfield (2011) demonstrated improved gelation properties of salt-extracted pea protein isolate (PPIs) through manipulation of heating temperature and heating rate, which could enhance competitiveness of PPI as functional additive.

Geerts *et al.* (2017) and Pelgrom, Boom, and Schutyser (2014) suggest that depending on the final application chemically less homogenous soluble pea protein fraction containing native protein conformations and small solutes, obtained through mild fractionation process could become a more sustainable and nutritional alternative for highly purified commercial ingredients with partially similar functional properties. Pea protein concentrate's emulsification properties and emulsion stability upon heat and freeze-thaw treatments were similar and more stable in Geerts *et al.* (2017) case. Pelgrom, Boom, and Schutyser (2014) established that upon heat-induced gelatinization, gel firmness was mainly increased by the presence of starch, while the presence of dispersed components (protein and/or fibre patches) in the gel weakened its structure.

Bessada, Barreira, & Oliveira (2019) concluded that despite the highlighted advantages, exploring peas (besides other pulses) as protein sources, issues with selecting most optimal production and processing technologies to improve their rheological and sensorial properties still need to be addressed.

Lu, Donner and Liu (2018) applied roasting and alginate encapsulation of pea starch fraction with the aim to enhance the amount of slowly digestible starch and resistant starch in the processed pea products, because most part of isolated pea starch after gelation becomes rapidly digestible starch.

Pea in meat products' analogues

Individual pea fractions (protein, starch and fibre) have been used as functional ingredients in analogue meat products: textured pea protein for formation of analogue 'fibrous' texture with neutral taste, pea starch as a binder to ensure binding properties of meat proteins and pea fibre as texture modifying agents best to mimic meaty texture (Bedin *et al.*, 2018; Pietrasik *et al.*, 2020).

Above described pea protein properties and possible modifications to enhance their functional properties, including good capacity in fat/ water binding, allowing adequate texture, emulsification, and gelation, have been employed in development and production of plant based meat alternatives (listed in Table 2). Pietrasik *et al.*, (2020) established that pea starch and fibre can be utilized as gluten free alternatives to wheat crumb for meat binder applications without impact on consumer acceptability.

Bedin *et al.* (2018) saw that most challenging task when developing new vegan foods is to find the most suitable recipe for vegans accepted meat products analogues. One should cope with the consumer's preferences on one side and take into consideration issues of product's expected texture and shelf life, on the other hand (Bedin *et al.*, 2018). In their case, product recipes with 80–92% of pea textured proteins provided ready product with very compact, rigid consistency, which could easily break or be extremely fibrous. Adding of gluten proteins to the recipe with pea textured proteins as a base resulted in ready product with consistency and texture analogous to the original products (Bedin *et al.*, 2018). But most successful recipes in terms of preserving the elasticity, typical of the traditional meat-based products for two traditional Italian meat product alternatives were acquired when solely wheat proteins were used (17.0–23.4%) (Bedin *et al.*, 2018).

Pea protein in dairy products' alternatives

Emulsifying properties of food oil-in-water systems of pea proteins and protein isolates are directly related to protein structure, molecular weight, conformational stability, amino acid composition (charged or neutral, polar or non-polar), water solubility, and surface hydro-phobicity (or -philicity), as well as temperature, pH, or ionic strength (Bessada, Barreira, & Oliveira, 2019).

Pea protein nutritional and functional properties and ability of its fractions to form soft gels (analogue to whey protein) could be employed in the development and production of dairy analogues – drinks, fermented products, curd. Solubility is an important property for functional ingredients in high moisture foods, such as emulsions, foams, and beverages. Pea protein isolate's (PPI) lower solubility and chalky mouth-feel in protein beverages are determined by high amount

of salt-soluble globulin with a predominant β -sheet structure (Carbonaro, Maselli, & Nucara, 2015; Lan *et al.*, 2019). Lan *et al.* (2019) established that with solid dispersion-based spray-drying processing PPI's functional properties (especially water solubility) were improved, and they were strongly affected by the type and ratio (to PPI) of added amorphous matrix carrier (gum arabic or maltodextrin). Additionally, the use of amorphous matrix carrier (gum arabic and maltodextrin) assisted in unfolding of PPI's secondary structure, which decreased contents of beany flavour markers (1-pentanol and 1-octen-3-ol); however, accelerated lipid oxidation (producing off-flavour compounds) could still occur during high temperature spray-drying (Lan *et al.*, 2019). Zha *et al.* (2019) observed that emulsifying properties and flavour profile of pea protein concentrate (PPC) conjugated with gum arabic (polysaccharide) through Maillard reaction were enhanced; thus, it could promote the utilization of pea proteins as functional ingredients in food industry.

Youssef *et al.* (2016) observed that the partial substitution of milk protein with pea protein did not enhance the physico-chemical characteristics of fermented dairy gels studied and dramatically reduced the quality of products regarding their texture and flavour profiles (Youssef *et al.*, 2016). The intensity of negative sensory profile's descriptors (earth, smoked, pea, acid and fluid) increased with enhanced pea protein ratio.

Ben-Harb *et al.* (2020) established that microbial consortia can efficiently reduce off-notes (majorly decreased concentrations of 'green aldehydes') and increase volatile aroma compounds in gels enriched with pea proteins. They proposed that fermentation could be successfully applied to develop plant-based protein food products with diversified sensory characteristics, and the composition of the gel essentially dictates metabolic activity and growth of the microbial community (Ben-Harb *et al.*, 2020).

Plant-based cheese from corn and tapioca starches, vegetable oils and PPI showed no functional applicability in the creation of plant-based cheeses lacking desired melting behaviour and other sensory properties when compared to Cheddar cheese (Mattice & Marangoni, 2020).

Conclusions

Field pea chemical composition directly indicates what kind of nutritional and health benefits are gained when consuming whole pea or its fractions, and there is vast scientific data to confirm that. Pea protein, starch and fibre have demonstrated functional properties in different food systems, including – emulsification, oil-in-water system stabilisation, texture modification, binding, gelation, foaming and solubility. Mostly

pea protein ingredients (isolates, concentrates) have been used in commercially available novel vegan foods as a source of protein. Pea protein functional properties and degree of purity depend on methods used to extract/fractionate specific pea protein

ingredient and food system where it is intended to be used. It is functionally possible and nutritionally, and ecologically desirable to develop novel vegan foods intended as animal product alternatives with acceptable sensory properties.

References

- Bansal, P., & Bansal, V. (2019). Dry Pea: Production Driven by Demand for Animal Feed. In D. K. Navarro & V. Rawal (Eds.), *The Global Economy of Pulses*, 1st ed. (pp. 99–106). Rome: FAO.
- Bedin, E., Torricelli, C., Gigliano, S., De Leo, R., & Pulvirenti, A. (2018). Vegan foods: Mimic meat products in the Italian market. *International Journal of Gastronomy and Food Science*, 13, 1–9. DOI: 10.1016/j.ijgfs.2018.04.003.
- Beitane, I., & Krumina-Zemture, G. (2017). Dietary micronutrient content in pea (*Pisum Sativum* L.) and buckwheat (*Fagopyrum Esculentum* M.) flour. In E. Straumite (Ed.), 11th Baltic Conference on Food Science and Technology 'Food science and technology in a changing world' (Vol. 700, pp. 56–60). DOI: 10.22616/foodbalt.2017.007.
- Ben-Harb, S., Irlinger, F., Saint-Eve, A., Panouillé, M., Souchon, I., & Bonnarne, P. (2020). Versatility of microbial consortia and sensory properties induced by the composition of different milk and pea protein-based gels. *LWT—Food Science and Technology*, 118, 21. DOI: 10.1016/j.lwt.2019.108720.
- Bessada, S.M.F., Barreira, J.C.M., & Oliveira, M.B.P.P. (2019). Pulses and food security: Dietary protein, digestibility, bioactive and functional properties. *Trends in Food Science and Technology*, 93(228), 53–68. DOI: 10.1016/j.tifs.2019.08.022.
- Boye, J., Zare, F., & Pletch, A. (2010). Pulse proteins: Processing, characterization, functional properties and applications in food and feed. *Food Research International*, 43(2), 414–431. DOI: 10.1016/j.foodres.2009.09.003.
- Carbonaro, M., Maselli, P., & Nucara, A. (2015). Structural aspects of legume proteins and nutraceutical properties. *Food Research International*, 76(P1), 19–30. DOI: 10.1016/j.foodres.2014.11.007.
- Cheng, M., Qi, J.R., Feng, J.L., Cao, J., Wang, J.M., & Yang, X.Q. (2018). Pea soluble polysaccharides obtained from two enzyme-assisted extraction methods and their application as acidified milk drinks stabilizers. *Food Research International*, 109, 544–551. DOI: 10.1016/j.foodres.2018.04.056.
- Dahl, W.J., Foster, L.M., & Tyler, R.T. (2012). Review of the health benefits of peas (*Pisum sativum* L.). *British Journal of Nutrition*, 108 (Suppl. 1). DOI: 10.1017/S0007114512000852.
- De Almeida Costa, G.E., Da Silva Queiroz-Monici, K., Pissini Machado Reis, S.M., & De Oliveira, A.C. (2006). Chemical composition, dietary fibre and resistant starch contents of raw and cooked pea, common bean, chickpea and lentil legumes. *Food Chemistry*, 94(3), 327–330. DOI: 10.1016/j.foodchem.2004.11.020.
- FAOSTAT. (2020). FAOSTAT. Retrieved February 6, 2020, from <http://www.fao.org/faostat/en/#data/QC/visualize>.
- Geerts, M.E.J., Mienis, E., Nikiforidis, C.V., van der Padt, A., & van der Goot, A.J. (2017). Mildly refined fractions of yellow peas show rich behaviour in thickened oil-in-water emulsions. *Innovative Food Science and Emerging Technologies*, 41, 251–258. DOI: 10.1016/j.ifset.2017.03.009.
- Hoover, R., Hughes, T., Chung, H.J., & Liu, Q. (2010). Composition, molecular structure, properties, and modification of pulse starches: A review. *Food Research International*, 43(2), 399–413. DOI: 10.1016/j.foodres.2009.09.001.
- Kalogeropoulos, N., Chiou, A., Ioannou, M., Karathanos, V.T., Hassapidou, M., & Andrikopoulos, N.K. (2010). Nutritional evaluation and bioactive microconstituents (phytosterols, tocopherols, polyphenols, triterpenic acids) in cooked dry legumes usually consumed in the Mediterranean countries. *Food Chemistry*, 121(3), 682–690. DOI: 10.1016/j.foodchem.2010.01.005.
- Kirse, A., & Karklina, D. (2014). Attitudes of Latvian adults to the consumption of pulses. In *Research for Rural Development*, 21–23 May 2014, (pp. 130–137). Jelgava: Latvia University of Agriculture.
- Krumina-Zemture, G., Beitane, I., & Gramatina, I. (2016). Amino acid and dietary fibre content of pea and buckwheat flours. In *Research for Rural Development*, 18–20 May 2016, (pp. 84–90). Jelgava: Latvia University of Agriculture.
- Lan, Y., Xu, M., Ohm, J. B., Chen, B., & Rao, J. (2019). Solid dispersion-based spray-drying improves solubility and mitigates beany flavour of pea protein isolate. *Food Chemistry*, 278, 665–673. DOI: 10.1016/j.foodchem.2018.11.074.

- Lu, Z.-H., Donner, E., & Liu, Q. (2018). Effect of roasted pea flour/starch and encapsulated pea starch incorporation on the in vitro starch digestibility of pea breads. *Food Chemistry*, 245(Supplement C), 71–78. DOI: 10.1016/j.foodchem.2017.10.037.
- Mattice, K.D., & Marangoni, A.G. (2020). Physical properties of plant-based cheese products produced with zein. *Food Hydrocolloids*, 105, 105746. DOI: 10.1016/j.foodhyd.2020.105746.
- Messina, M., & Venter, C. (2020). Recent Surveys on Food Allergy Prevalence. *Nutrition Today*, 55(1), 22–29. DOI: 10.1097/nt.0000000000000389.
- Michaels, T.E. (2015). *Grain Legumes and Their Dietary Impact: Overview*. In the World of Food Grains (Vol. 1–4, pp. 265–273). Elsevier Inc DOI: 10.1016/B978-0-12-394437-5.00040-1.
- Moreno, H.M., Domínguez-Timón, F., Díaz, M.T., Pedrosa, M.M., Borderías, A.J., & Tovar, C.A. (2020). Evaluation of gels made with different commercial pea protein isolate: Rheological, structural and functional properties. *Food Hydrocolloids*, 99, 105375. DOI: 10.1016/j.foodhyd.2019.105375.
- Osmane, B., Konosonoka, I. H., Proskina, L., & Cerina, S. (2016). Chemical composition of various pea and bean varieties grown in Latvia. In *Engineering for Rural Development*, 25–27 May 2016, (pp. 262–267). Jelgava: Latvia University of Agriculture.
- Pelgrom, P.J.M., Boom, R.M., & Schutyser, M.A.I. (2014). Functional analysis of mildly refined fractions from yellow pea. *Food Hydrocolloids*, 44, 12–22. DOI: 10.1016/j.foodhyd.2014.09.001.
- Pietrasik, Z., Sigvaldson, M., Soladoye, O.P., & Gaudette, N.J. (2020). Utilization of pea starch and fibre fractions for replacement of wheat crumb in beef burgers. *Meat Science*, 161(October 2019), 107974. DOI: 10.1016/j.meatsci.2019.107974.
- Rawal, V., Charrondiere, R., Maria, X., & Fernanda, G. (2019). Pulses: Nutritional Benefits and Consumption Patterns. In V. Rawal & D. K. Navarro (Eds.), *The Global Economy of Pulses* 1st ed., pp. 9–19). Rome: FAO.
- Regulation No 1308/2013 of the European Parliament and of the Council (2013). Retrieved February 6, 2020, from <https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:02013R1308-20190101&qid=1583485376550&from=LV>.
- Rohn, S., & van Griensven, L. (2015). Grain legumes and further gluten free legumes—Science, technology and impacts on human health. *Food Research International*, 76, 1–2. DOI: 10.1016/j.foodres.2015.03.010.
- Roy, F., Boye, J.I., & Simpson, B.K. (2010). Bioactive proteins and peptides in pulse crops: Pea, chickpea and lentil. *Food Research International*, 43(2), 432–442. DOI: 10.1016/j.foodres.2009.09.002.
- Shand, P.J., Ya, H., Pietrasik, Z., & Wanasundara, P.K.J.P.D. (2007). Physicochemical and textural properties of heat-induced pea protein isolate gels. *Food Chemistry*, 102(4), 1119–1130. DOI: 10.1016/j.foodchem.2006.06.060.
- Singh, B., Singh, J.P., Kaur, A., & Singh, N. (2017). Phenolic composition and antioxidant potential of grain legume seeds: A review. *Food Research International*, 101(June), 1–16. DOI: 10.1016/j.foodres.2017.09.026.
- Sun, X.D., & Arntfield, S.D. (2011). Gelation properties of salt-extracted pea protein isolate induced by heat treatment: Effect of heating and cooling rate. *Food Chemistry*, 124(3), 1011–1016. DOI: 10.1016/j.foodchem.2010.07.063.
- Tayeh, N., Aubert, G., Pilet-Nayel, M.L., Lejeune-Hénaut, I., Warkentin, T.D., & Burstin, J. (2015). Genomic tools in pea breeding programs: Status and perspectives. *Frontiers in Plant Science*, 6(November), 1–13. DOI: 10.3389/fpls.2015.01037.
- Van Dooren, C., Marinussen, M., Blonk, H., Aiking, H., & Vellinga, P. (2014). Exploring dietary guidelines based on ecological and nutritional values: A comparison of six dietary patterns. *Food Policy*, 44, 36–46. DOI: 10.1016/j.foodpol.2013.11.002.
- Yang, H., Guérin-Deremaux, L., Zhou, L., Fratus, A., Wils, D., Zhang, C., ... Miller, L.E. (2012). Evaluation of nutritional quality of a novel pea protein. *Agro Food Industry Hi-Tech*, 23(6), 8–10.
- Youssef, M., Lafarge, C., Valentin, D., Lubbers, S., & Husson, F. (2016). Fermentation of cow milk and/or pea milk mixtures by different starter cultures: Physico-chemical and sensorial properties. *LWT—Food Science and Technology*, 69, 430–437. DOI: 10.1016/j.lwt.2016.01.060.
- Zha, F., Dong, S., Rao, J., & Chen, B. (2019). The structural modification of pea protein concentrate with gum Arabic by controlled Maillard reaction enhances its functional properties and flavor attributes. *Food Hydrocolloids*, 92, 30–40. DOI: 10.1016/j.foodhyd.2019.01.046.

FACTORS AFFECTING SMOKED FISH QUALITY: A REVIEW

***Santa Puke, Ruta Galoburda**

Latvia University of Life Sciences and Technologies, Latvia

*Corresponding author's email: santa_puke@inbox.lv

Abstract

Smoked sprats (*Sprattus sprattus balticus*) from the Baltic sea are one of the most popular processed fish products in Latvia. The amount of catching and demand is annually increasing. For producers, it is important to provide stable quality throughout the year, which sometimes is challenging due to many factors. Smoked fish quality depends not only on the seasonality, but also on the applied technologies. The aim of the current study was to review research findings about factors affecting the smoked fish quality. The databases of Science Direct, Web of Science, Wiley Online Journals and Google Scholar were searched. The first parameter that affects quality of fish till processing is raw material, its catching place and season, as well as whether it is fresh or frozen fish, that includes not only microbiological parameters, but also physical and chemical changes in fish depending on the storage conditions. The second parameter is the applied pre-treatment methods (using salt, acids) before processing, which can improve fish texture and make better result for smoked fish. The third parameter is the used technology for the fish processing, heat treatment methods use of wood chips or liquid smoke, or adjustment of smoking conditions. These all together make a lot of sensorial and textural changes in the final product. If any of these parameters is changed during processing, they can affect the smoked fish quality. Therefore, to ensure constant quality of smoked fish, in-depth knowledge of parameters is extremely important.

Key words: pre-treatment, smoked sprat, seasonality, fresh and frozen sprats, smoking.

Introduction

Each year catching amount of sprats (*Sprattus sprattus balticus*) is increasing because of increased consumption of fish products. Besides the increased consumption, customers pay more attention to the quality – sensory parameters including textural parameters (consistency, juiciness) as well as nutritional components (lipids, protein). Fish consumption has a positive effect on human health. It is nutritionally valuable product, and good source of protein; it also contains valuable lipids (omega-3 fatty acids), minerals and vitamins (Mohanty *et al.*, 2019). Fish lipids contain polyunsaturated fatty acids (PUFA) with up to 6 double bonds - eicosapentaenoic acids (EPA) and docosahexaenoic acid (DHA) (Stołyhwo, Kołodziejka, & Sikorski, 2006).

Sprats are small commercial fish from *Clupeidae* family and their size from the sea is about 10–20 cm. They live in shoals and feed on zooplankton, spawning season usually varies depending on a geographical location, but in the Baltic sea it is from March till June (Timberg *et al.*, 2014). Sprats contain a lot of water (57–73%) and lipids (10–24%). There is inverse relationship between water and lipids, which means that lower water content makes higher lipid content and contrary (Timberg *et al.*, 2011). Sprats are rich in vitamin D, minerals like potassium, iron, zinc, iodine (Usydus, Szlifder-Richert, & Adamczyk, 2012). Baltic sprats are rich source of PUFA and stability of these fatty acids is influenced by the storage conditions and pre-treatment methods.

Raw product quality is the main parameter, which affects finished products quality. Fish is easily spoiled due to oxidation and developing off-flavours. Cooling can maintain freshness, but it

does not eliminate microorganisms or enzymatic activity, the psychotropic bacteria will still live under chilled conditions (Wu, Pu, & Sun, 2019). As quality changes along the year, it is important to find the main technological parameters, which should be adjusted to ensure constant quality of the final product.

The aim of the current study was to review research findings about factors affecting the smoked fish quality.

Materials and Methods

The research was performed by using monographic method to review factors influencing smoked fish quality. The databases of Science Direct, Web of Science, Wiley Online Journals and Google Scholar were searched. No time restrictions were applied, and all articles were selected in January – February, 2020. The aim of the current study was to review research findings about factors affecting the smoked fish quality parameters, which can affect the quality of the product, find out the main quality parameters, and determine how to ensure the constant quality using some pre-treatment methods or selecting the most appropriate heat treatment method.

Results and Discussion

The smoked fish quality depends on various factors, which can be grouped as shown in Figure 1. To provide constant quality of the finished product all parameters should be considered and necessary adjustments made in the processing technologies.

Raw material

The raw material quality is the main factor affecting smoked fish quality. Raw material quality has intrinsic factors like size, fat content and skin properties, that

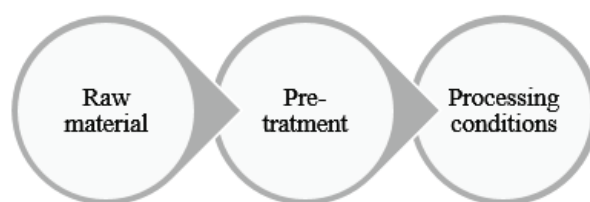


Figure 1. The main factors affecting smoked fish quality.

mean small fish like sprats spoil faster than large fish (Zugarramurdi *et al.*, 2004). Quality parameters are affected by seasonality, sex, age, and geographical location, these all make changes in fish lipids and proteins (Abbas *et al.*, 2008). Sprats are fatty fish and valuable dietary source of proteins, polyunsaturated fatty acids from n-3 family. Cooling or transporting conditions have great influence on processed fish quality. Fatty fish does not store as long as lean fish in aerobic conditions, because of fat oxidation processes. They also have higher influence on the quality of final products (Zugarramurdi *et al.*, 2004). There are no correlations established between lipid oxidation and content of lipids in thawed fish. Temperature and some smoke compounds can affect fish lipids and proteins (Kołodziejaska & Sikorski, 2004).

According to Timberg *et al.* (2011) in spring, when is spawning season, the Baltic sprat lipid content was low $13 \pm 1.6\%$, but in autumn, end of feeding season (October, November) the highest $22 \pm 3\%$. Similar trend was reported by Usydus, Szlifder-Richert, Adamczyk (2012), see Table 1. Protein was stable through seasons, being about 15%. That means that autumn sprats (the end of feeding season and all wintering season) have the highest lipid content, but in spring (spawning season) – the highest water

content. In spring and summer, the content of lipids is the lowest and it has influence on the textural and sensorial properties. It makes changes in sensorial parameters – less intense aroma and flavour and makes softer texture (Timberg *et al.*, 2011). Additionally, it has been reported that proximate composition and fatty acids profile in muscle depend on seasonality of Baltic sprats. Fish up to 10 cm have different indicators than class 10–13 and over 13 cm (Usydus, Szlifder-Richert, & Adamczyk, 2012).

Raw material freshness and quality of the finished product have close relationship. For all fish products, its freshness has the most essential role. It includes shelf life of fish, bacterial flora, and storage conditions. Abbas *et al.*, (2008) reported that pH of European sea bass (*Dicentrarchus labrax*) increased from 6.39 till 6.69, trimethylamine – N (from trimethylamine volatile basis) from 0.20 till 1.25 N 100 g⁻¹ flesh, total volatile basic – N from 17.22 till 30.58 mg N 100 g⁻¹ flesh, free fatty acids from 1.78 till 2.73 g oleic acid per 100 g lipids, but content of trimethylamine oxide decreased from 22.08 till 12.55 mg N 100 g⁻¹ flesh during storage period from 1 till 22 days in ice. Initial pH decrease occurs because glycogen in the fish muscle has been metabolized to lactic acids. Fresh live fish pH is 7, and during further storage it increases

Table 1

Proximate nutritional composition in muscle of Baltic sprat depending on catch season
(Usydus, Szlifder-Richert, & Adamczyk, 2012)

Indicator	Feeding season (July – October)	Wintering season (November – February)	Spawning season (March – June)
Moisture, %	66.40 ± 1.69	70.71 ± 2.43	77.48 ± 1.81
Protein, %	17.06 ± 0.46	16.74 ± 0.41	16.61 ± 0.33
Lipid, %	15.46 ± 2.02	11.34 ± 2.07	5.10 ± 0.87
Saturated fatty acids, %	28.37 ± 0.24	29.08 ± 1.55	28.64 ± 2.12
Monounsaturated fatty acids, %	32.78 ± 1.07	31.56 ± 5.96	35.63 ± 4.41
Polyunsaturated fatty acids%, including:	38.85 ± 0.96	39.28 ± 4.73	35.75 ± 2.36
-eicosapentaenoic acid, %	8.40 ± 0.65	8.05 ± 1.42	4.97 ± 1.29
-docosahexaenoic acid, %	17.67 ± 0.69	18.17 ± 2.20	17.93 ± 1.18
Individual weight, g	12.48 ± 2.87	12.38 ± 4.03	12.00 ± 1.93

because of production of alkaline enzymes, and if fish spoiling starts, there can be an increase in total volatile basic – N. Abbas *et al.* (2008) suggest to use fish pH as an indicator of fish freshness.

Wild fish can be harvested by a large variety of methods. To control stress produced by these conditions, it is necessary to control mainly fishing method and time. Incorrect handling can determine the quality changes during storage. If fish are caught in a highly stressed state, their lactic acid produced in muscle combined with high muscle temperature results in a dull muscle, and it makes acidic or metallic aftertaste (Borderías & Sánchez-Alonso, 2011). In this case, *rigor mortis* proceeds faster and quality is lower. The stiff and rigid condition of muscle tissues is *rigor mortis*, it starts about 1 till 6 hours after death (Hamada-Sato *et al.*, 2005). If large fish are killed faster, stress is less and quality is better. Stress before catching and before death have effect on quality. From biochemical factors after catch, its muscle cells contain more lactic acids from anaerobic respiration and *rigor mortis* sets sooner. Post-mortem pH in fish flesh on fish catching vessels have the effect on texture of fish, in that case it is very important to make faster cooling on vessels (Zugarramurdi *et al.*, 2004). Chilling rate has an important role in the final product quality and especially in texture. In highly stressed fish all muscles enter *rigor mortis* very quickly all fish go very stiff and difficult to process. Texture of stressed fish was softer during storage (Borderías & Sánchez – Alonso, 2011).

Spoilage of fish starts as soon as the fish die after fishing, and spoilage varies with species, handling methods, hygienic and chilling conditions and methods; there is an influence from microorganisms (Solanki *et al.*, 2016). Thiobarbituric acid (TBA) and peroxide value (PV) are two commonly used parameters for the evaluation of lipid oxidation and decomposition of protein (Wu, Pu, & Sun, 2019).

High moisture content and nutrients in fish facilitate the growth of many microorganisms including pathogens (*Listeria monocytogenes*, *Escherichia coli*, *Salmonella* spp.), which can affect not only the fish quality, but also product safety. *Listeria* spp. and *Salmonella* spp. are naturally present in aquatic environment and their presence can be contaminated with already infected fish. *Escherichia coli* indicates poor hygiene conditions during storage or transporting (Eizenberga *et al.*, 2015). As sprats are cold-water fish, they can carry *Shewanella putrefaciens* and can spoil faster than warm water fish. Storage conditions using 40% ice and 60% water or with additionally injected ozone can increase shelf life up to 13 – 16 days, but it is prolonged by 8 days when normal ice is used. Ozone and organic acids have natural antioxidants (Sampels, 2015b). Free histidine

is generally found in fatty fish, red meat fish and *Enterobacteriaceae*, *Clostridium* and *Lactobacillus* produce histidine decarboxylase and for growing histamine forming bacteria most important is coliform bacteria. Histamine forming bacteria naturally exist on the gills and in salt water fish. Only rapid chilling after catch immediately can prevent forming of these bacteria, and enzyme, bacteria can be inactivated by cooking, but once histamine is produced, it cannot be eliminated by heating or freezing. Fish may contain pathogenic bacteria *Clostridium botulinum* (type E), *Staphylococcus aureus*, *Vibrio parahaemolyticus* and it grows in raw fish. Its growth is decreased in frozen fish, or in cold storage (0 till 4 °C) (Köse, 2010). In fresh fish (sprats) the histamine was detected from 5 samples in 3 samples when fish were smoked. And if in fresh fish amount of histamine were determined 1.4 till 5.2 mg kg⁻¹, in smoked it increased to 1.8 till 24.1 mg kg⁻¹ (Pawul-Gruba, Michalski, & Osek, 2014).

Freezing and thawing of raw material

Freezing slows the biological, chemical, and physical deterioration of food, degradation of food quality (colour, texture, lipid oxidation, enzymatic activity). Quality loss in frozen fish has been attributed to protein denaturation, which correlates strongly with loss of sensory quality. During freezing microbiological growth is suspended, but not enzymatic activity (Ruiz-Capillas, 2000). Biological and chemical reactions such as enzymatic activity and lipid oxidation have significant impact on fish quality during long-term frozen storage. The total lipid and ash content vary with size and catching season of the fish. Storage time and temperature affect quality loss and the shelf life of fish, lipid content decreased from 9.72% till 7.20% in tilapia (*Oreochromis niloticus*) (Dawson, Al-Jeddawi, & Remington, 2018). Red muscles contain high levels of lipids and are sequentially subject to lipid oxidation. Trimethylamine oxides are found within the red muscle that can be enzymatically or non-enzymatically degraded, resulting in products such as dimethylamine and formaldehyde. Some researchers – Dawson, Al-Jeddawi, & Remington (2018) – found fatty acid (C16:1) decrease in meat fat during frozen storage, while no decrease in polyunsaturated fatty acids (PUFA). Peroxide value is an early indicator of oxidation.

Freezing preserves fish longer time, but it also may have negative effect on structural and chemical properties of muscle. The faster and more homogeneous freezing proceeds, the smaller ice crystals are made and it makes less textural damage to muscle fibre (Sampels, 2015b). Slow freezing can result in formation of big ice crystals, which can destroy cell membranes and it increases a risk of oxidation, texture damage and loss of water holding capacity. During frozen fish storage it is very important to keep stable temperature to prevent

the growth of ice crystals (Sampels, 2015a). During thawing, ice crystals melt, and if formed intracellularly or around muscle tissue, moisture would remain within the fish. Water holding capacity is commercially very important to appearance and texture.

Frozen fish storage leads to reduction of protein extractability and reduction of water holding capacity. Freezing before smoking has small physicochemical characteristic on flesh. In frozen fish storage, the myofibrillar proteins can lead to denaturation in the functional properties of fish muscle proteins and make changes in texture due to the loss of water holding capacity. Protein denaturation reduces amount of soluble proteins. Freezing before smoking has a negative effect on fish flesh adhesiveness, cohesiveness (textural properties), smoke odour intensity and colour intensity (Martinez *et al.*, 2010). Generally, sprats made from frozen thawed raw materials has the same texture as the same product made from fresh sprats. However, it is possible that sprats made from frozen thawed fish had a tendency to be harder and sour, the rancid taste developed more rapidly than samples made from fresh fish. Freezing and thawing may damage the protein native structure making it susceptible to further reactions (Timberg *et al.*, 2014).

Pre-treatment methods

Preserving fisheries products for a long storage time can be done by either lowering water activity (a_w) or changing pH of products. Preservation can also be carried out by applying antibacterial activity of salt and smoke components. Pre-treatment methods have not only preservation options, but also provide better sensorial properties of products.

Salting is one of the traditional preservation processes, when salt works as preservative that penetrates the tissue. Salt separates water from fish and replaces it with salt. Thus, water concentration in fish decreases. During salting, water activity a_w can reach 0.8 to 0.7. (Many pathogenic organisms cannot survive these conditions. Salting protected chub mackerel from oxidation (Sampels, 2015a). Replacing NaCl to KCl as well as the addition of ascorbic acid to the brine solution decreased lipid oxidation in salted mackerel. Replacing sodium with potassium about 25% can reduce amount of sodium in human dietary, but sodium and potassium have similar properties. If the amount is more than 25%, it makes a bitter taste. The uptake of salt into fish muscle depends on salting procedure, salt concentration used in brine, fish species, size, thickness. Protein loss depends also on the salt content (Sampels, 2015a). The size, thickness of the fish, with or without skin and scales, if fish is or not in rigor mortis, the freshness of fish it all affects the ripening process. The ripening of salted fish is a biochemical process, where enzymes cause

degradation of fish muscle compounds. If pH increases, the quality of fish decreases (Bonoco & Kurt Kaya, 2018). Salting preserves fish from decomposition and minimize oxidation of the lipids. It reduces moisture in fish muscle. During salting characteristic flavour and texture of finished products are developed.

Brine concentration and brining time affected the texture development. There is little information about salt concentration effect on the shelf life of smoked fish (Yanar, Çelik, & Akamca, 2006). The flavour, odour and texture changed during the storage at rates depending on the storage temperature. The higher salt concentrations prevented some growth of halophiles. Storage in lower temperature with higher salt concentration increased shelf life of brined anchovies (Karaçam, Kutlu, & Köse, 2002). The highest water content in canned catfish was in 3% brine solution. That means that the use of different brine concentration of solution has an effect on nutrient values (Herawati *et al.*, 2016).

Marinating preserves fish through the simultaneous action of salt and organic acids. Marinating is used to tenderize, change textural and structural properties of raw material. It increases ionic strength and decreases the pH, it also makes tender texture, better structural properties and changes the taste (Çağlak, 2015). Salt and acids diffuse into the fish muscle, denature the protein and lower the pH value and activating the lysosomal cathepsins, which makes typical flavour. Texture is very important quality parameter. Low pH induced protein denaturation and makes harder texture (Serdaroglu *et al.*, 2015). Marinating improves flavour and textural properties, it slows down the bacterial and enzyme activity and provides taste, tenderness, textural and structural changes. In marinating process relative amounts of fat, protein, ash increases, because of water loss by penetration of salt into meat. Containing 10% NaCl and 4% acetic acid can extend the shelf life of the product in refrigerated storage conditions (Pop & Frunză, 2015).

Application of salting or brining prior to smoking improves functional properties. Toughness and hardness are important textural attributes, and they depend on the connective tissue containing collagen, which is responsible for tensile strength and the myofibrils consisting of myosin and actin (Burgaard, 2010). Dhanapal *et al.* (2013) advised fish dipped in 10% salt concentration for 60 min were found improving the colour and textural quality based on sensory evaluation. Fish brined with 8–10% salt about an hour was sufficient to remove slime and harden the fish flesh. Brining 15 min in salt solution makes 1.1–1.6% as NaCl in finished product. Adding 25% calcium chloride to 75% NaCl for 3 hour provides a proper firm texture to the meat (Zakipour Rahimabadi

& Faralizadeh, 2016). Cooked fish usually tend to become soft in texture comparing with raw fish, because the heat induces the conversion of collagen to gelatin in fish flesh, and darkening of the fish muscle because of Maillard reaction (Dhanapal *et al.*, 2013).

Processing conditions

Smoking creates new products with specific sensorial characteristics and texture. Already in ancient times smoking was used as a fish preservation method, which added not only specific flavour and colour to the product, but also it made smoke compounds work as antimicrobial agents (Tahsin *et al.*, 2017). It is critical to understand the changes occurring in the fish, because it may reduce the quality in processing.

Hot smoking is carried out in several stages, when the temperature is increased from 40 till 100 °C, while in the product it reaches at least 85 °C. The content of polycyclic aromatic hydrocarbons (PAH) depends on temperature of smoke generation (Stołyhwo & Sikorski, 2005). The smoking itself also has a drying effect, and it decreases the water activity and increases inhibition of bacterial growth. Combination of liquid smoke with traditional smoke inhibited lipid oxidation (Sampels, 2015a).

Over 400 compounds identified in wood smoke, so far 40 acids, 22 alcohols, 131 carbonyls, 22 esters, 46 furans, 16 lactones and 75 phenols. Wood smoke contains also about 61 compounds of PAH (Stołyhwo & Sikorski, 2005). According to the report of the European Food Safety Authority (EFSA) beech (*Fagus sylvatica*) wood is the most common wood used for smoking food. All smoke compounds arise during the pyrolysis of the wood compounds, and are responsible for preservation and antimicrobial effect of the smoke. The typical smoke flavour is mainly related to the phenolic compounds in the smoke. The most active wood smoke compounds in traditional smoking are pyrogallol, resorcinol, 4-methylguaiacol, less active is syringol, guaiacol (Stołyhwo, Kołodziejska, & Sikorski, 2006). In liquid smoke, traditional compounds in smoke are syringol and cresols that give cold smoke sensory attributes. The content of syringol in hardwood smoke is higher than the content of guaiacol due to the different structure of lignin in hardwood and softwood (Hitzel *et al.*, 2014). Toledo (2008) observed that some of phenols in smoke are similar to spices, eugenol like cinnamon, pepper, and nutmeg. The flavour of smoke components depends on concentration. Lingbeck *et al.* (2014) found the amount of phenols in liquid smoke condensates is about 9.9 till 11.1 mg mL⁻¹. Recommended amount to use liquid smoke varies from 0.4% till 4%. But smoke compounds depend on smoke generation (kind of wood, wood moisture, temperature, air quantity) (Sérot *et al.*, 2009).

Smoking increases shelf life of fish due to dehydration; it has antimicrobial and antioxidant

effects from the smoke components such as formaldehyde, phenols and carboxylic acids. Stołyhwo, Kołodziejska, & Sikorski, (2006) found out that due to phenols ring structure with conjugated double bonds, which are able to build stable radicals, the phenolic smoke compounds have antioxidative effects, but that effect has an influence from the extent of water loss in smoking process.

The smoking decreased the content of saturated fatty acids and increased content of PUFA. The higher PUFAs content can be explained by the fact that saturated fatty acids and mono unsaturated fatty acids are largely represented in neutral lipids and are more prone to migration from processing (Zakipour Rahimabadi & Faralizadeh, 2016). Stołyhwo, Kołodziejska, & Sikorski, (2006) found out that by using liquid smoke the values of peroxide and TBA are lower than in traditional methods. Dry salting with addition of sugar before immersion in a liquid smoke makes product with lower oxidation, lower hardness, elasticity value (Sampels, 2015a).

After smoking the amount of most important amino acids, glycine and alanine were reduced, but glutamic acid gave fish umami taste (Swastawati *et al.*, 2016).

Texture is also one of the important properties of thermally processed food. Heating decreased water holding capacity of the muscle which resulted in loss of the muscle tenderness (Dhanapal *et al.*, 2013).

Colour is formed when smoke and food components react chemically at the elevated temperature and the combination of cold staining and heat induced Maillard reactions take place. Maillard and Strecker aldehydes are largely responsible for colour in smoked fish. Colour varies from golden yellow to dark brown according to the nature of the wood and intensity of smoking process (Varlet, Prost, & Serot, 2007). Toledo (2008) researched, when the product is heated, the carbonyl compounds react with the proteins in a Maillard reaction to produce the brown colour. Cold smoked products do not change colour, because there are not enough phenols to produce a stain and the Maillard reaction does not proceed far enough to develop the colour (Toledo, 2008).

Liquid smoke is one of the methods, which is becoming popular nowadays. Liquid smoke is easy to apply and easy to control (Swastawati *et al.*, 2012). For the use of liquid smoke, simple equipment is required, and concentration of smoke compounds is controlled. The best use is from 1% till 5%. Liquid smoke has not only bactericidal, but also bacteriostatic effect, and together they act as synergic preservative. It can inhibit all pathogenic bacteria (i.e. *Escherichia coli*, *Listeria monocytogenes*, *Staphylococcus aureus*). As sprats belong to the *Clupeidae* family fish, there is naturally occurring histidine in fish flesh.

Fish meat contains very little connective tissue and high natural cathepsin enzyme, so it is very easy to be digested by that autolysis enzyme, which makes softer the meat and makes it a good source for the growth of microorganisms – pathogenic bacteria and histamine-forming bacteria. Total bacteria count should not exceed 5×10^5 CFU g⁻¹ (Dien, Montolalu, & Berhimpon, 2019). The application of liquid smoke lowers pH (5.56–5.58), which is caused by organic acids of condensation in smoking process (Dien, Montolalu, & Berhimpon, 2019). The use of liquid smoke produces high quality smoked fish products, less moisture content, and lower salt, and microbiological parameters are better compared to the traditionally smoked fish products.

Conclusions

Raw material quality and its storage conditions are the important parameters for the smoked fish quality. Better raw fish quality can be provided, when reaching low storage temperature as fast as possible after catching. The selection of proper pre-treatment methods and technology can provide and ensure constant quality. Smoking conditions have a significant influence on the shelf life of product, and make changes in volatile compounds, and provide better sensory parameters and texture. Therefore, systematic research of factors and their combinations is necessary in order to achieve stable quality of smoked sprats (*Sprattus sprattus balticus*) from the Baltic sea.

References

- Abbas, K.A., Mohamed, A., Jamilah, B., & Ebrahimian, M. (2008). A review on correlations between fish freshness and pH during cold storage. *American Journal of Biochemistry and Biotechnology*, 4(4), 416–421. DOI: 10.3844/ajbbbsp.2008.416.421.
- Bonoco, A., & Kurt Kaya, G. (2018). Effect of brine and dry salting methods on the physicochemical and microbial quality of chub (*Squalius cephalus* Linnaeus, 1758). *Food Science and Technology*, 38, 66–70. DOI: 10.1590/1678-457x.15717.
- Borderías, A.J., & Sánchez-Alonso, I. (2011). First Processing Steps and the Quality of Wild and Farmed Fish. *Journal of Food Science*, 76(1), 1–5. DOI: 10.1111/j.1750-3841.2010.01900.x.
- Çağlak, E. (2015). Determination of shelf life of marinade and brine injected rainbow trout (*Oncorhynchus mykiss*, Walbaum 1792) at refrigerator conditions. *Journal of Food and Health Science*, 1(4), 199–2110. DOI: 10.3153/jfhs15019.
- Dawson, P., Al-Jeddawi, W., & Remington, N. (2018). Effect of Freezing on the Shelf Life of Salmon. *International Journal of Food Science*, 2018, 1–12. DOI: 10.1155/2018/1686121.
- Dhanapal, K., Nayak, B.B., Venkateshwarlu, G., Balasubramanian, A., Devivaraprasad Reddy, A.D., & Basu, S. (2013). Changes in Instrumental and Sensory Characteristics of Tilapia Fish Steaks During Cold Blanching and Cooking Treatments. *The Bioscan*, 8(3), 887–892.
- Dien, H.A., Montolalu, R.I., & Berhimpon, S. (2019). Liquid smoke inhibits growth of pathogenic and histamine forming bacteria on skipjack fillets. *IOP Conference Series: Earth and Environmental Science*, 278(1), 12018.
- Eizenberga, I., Terentjeva, M., Valciņa, O., Novoslavskij, A., Strazdiņa, V., Ošmjana, J., & Bērziņš, A. (2015). Microbiological quality of raw fish at retail market in Latvia. Proceedings of the 25th NJF Congress Nordic View to Sustainable Rural Development, 16–18 Jun. 2015, pp. 324–328.
- Hamada-Sato, N., Usui, K., Kobayashi, T., Imada, C., & Watanabe, E. (2005). Quality assurance of raw fish based on HACCP concept. *Food Control*, 16(4), 301–307. DOI: 10.1016/j.foodcont.2004.02.001.
- Herawati, E.R.N., Angwar, Susanto, A., & Kurniadi (2016). Effect of Brine Concentration on the Nutrient Content and Fatty Acid Profile of Canned Catfish [*Pangasius sutchi* (Fowler, 1937)]. *Aquatic Procedia*, 7, 85–91. DOI: 10.1016/j.aqpro.2016.07.011.
- Hitzel, A., Pöhlmann, M., Schwägele, F., Speer, K., & Jira, W. (2014). Polycyclic aromatic hydrocarbons (PAH) and phenolic substances in meat products smoked with different types of wood and smoking spices. *Food Chemistry*, 139(1–4), 955–962. DOI: 10.1016/j.foodchem.2013.02.011.
- Karaçam, H., Kutlu, S., & Köse, S. (2002). Effect of salt concentrations and temperature on the quality and shelf-life of brined anchovies. *International Journal of Food Science and Technology*, 37(1), 19–28. DOI: 10.1046/j.1365-2621.2002.00526.x.
- Kołodziejaska, I., & Sikorski, Z. (2004). Lipid oxidation and lysine availability in smoked Atlantic mackerel fillets and Baltic sprats. *Bulletin of the Sea Fisheries Institute* 3 (163), 13–21.
- Köse, S. (2010). Evaluation of Seafood Safety Health Hazards for Traditional Fish Products: Preventive Measures and Monitoring Issues. *Turkish Journal of Fisheries and Aquatic Sciences*, 10(1), 139–160. DOI: 10.4194/trjfas.2010.0120.

- Lingbeck, J.M., Cordero, P., O'Bryan, C.A., Johnson, M.G., Rieke, S.C., & Crandall, P.G. (2014). Functionality of liquid smoke as an all-natural antimicrobial in food preservation. *Meat Science*, 97(2), 197–206. DOI: 10.1016/j.meatsci.2014.02.003.
- Martinez, O., Salmerón, J., Guillén, M.D., & Casas, C. (2010). Effect of freezing on the physicochemical, textural and sensorial characteristics of salmon (*Salmo salar*) smoked with a liquid smoke flavouring. *LWT – Food Science and Technology*, 43(6), 910–918. DOI: 10.1016/j.lwt.2010.01.026.
- Mohanty, B.P., Mahanty, A., Ganguly, S., Mitra, T., Karunakaran, D., & Anandan, R. (2019). Nutritional composition of food fishes and their importance in providing food and nutritional security. *Food Chemistry*, 293 (August 2016), 561–570. DOI: 10.1016/j.foodchem.2017.11.039.
- Pawul-Gruba, M., Michalski, M., & Osek, J. (2014). Determination of histamine in fresh and smoked fish commercially available in Poland. *Bulletin of the Veterinary Institute in Pulawy*, 58(2), 301–304. DOI: 10.2478/bvip-2014-0046.
- Pop, I.M., & Frunzã, G. (2015). Study on the Nutritional Quality (*Scomber scomber*). *Scientific Papers-Animal Science Series*, 65(1), 143–147.
- Ruiz-Capillas, C. (2000). Quality of Frozen/Thawed Sprat (*Sprattus sprattus*) stored in cling film and aluminum foil at 4C. *Journal of Food Quality* 25, 1–11.
- Sampels, S. (2015a). The effects of processing technologies and preparation on the final quality of fish products. *Trends in Food Science and Technology*, 44(2), 131–146. DOI: 10.1016/j.tifs.2015.04.003.
- Sampels, S. (2015b). The Effects of Storage and Preservation Technologies on the Quality of Fish Products: A Review. *Journal of Food Processing and Preservation*, 39(6), 1206–1215. DOI: 10.1111/jfpp.12337.
- Serdaroglu, M., Baris, P., Urgu, M., Doostifard, E., & Yildiz-Turp, G. (2015). Quality changes of sardine fillets marinated with vinegar, grapefruit and pomegranate marinades. *Electronic Journal of Polish Agricultural Universities. Series Food Science and Technology*, 18(4) #09.
- Sérot, T., Baron, R., Cardinal, M., Catanéo, C., Knockaert, C., Bizec, B.L., Prost, C., Monteau, F., & Varlet, V. (2009). Assessment of the effects of the smoke generation processes and of smoking parameters on the organoleptic perception, the levels of the most odorant compounds and PAH content of smoked salmon fillets. Retrieved April 19, 2020, from <http://www.fao.org/tempref/docrep/fao/012/i0884b/i0884b02b.pdf>.
- Solanki, J., Parmar, H., Parmar, A., Parmar, E., & Masani, M. (2016). Freshness evaluation of fish by quality index method (QIM) and instrumental method at Veraval Fish Landing Centre. *International Journal of Processing and Post-Harvest Technology*, 7(1), 42–46. DOI: 10.15740/has/ijppht/7.1/42-46.
- Stołyhwo, A., Kołodziejka, I., & Sikorski, Z.E. (2006). Long chain polyunsaturated fatty acids in smoked Atlantic mackerel and Baltic sprats. *Food Chemistry*, 94(4), 589–595. DOI: 10.1016/j.foodchem.2004.11.050.
- Stołyhwo, A., & Sikorski, Z.E. (2005). Polycyclic aromatic hydrocarbons in smoked fish – A critical review. *Food Chemistry*, 91(2), 303–311. DOI: 10.1016/j.foodchem.2004.06.012.
- Swastawati, F., Boesono, H., Susanto, E., & Setyastuti, A.I. (2016). Changes of Amino Acids and Quality in Smoked Milkfish [*Chanos chanos* (Forsk. 1775)] Processed by Different Redestillation Methods of Corncob Liquid Smoke. *Aquatic Procedia*, 7, 100–105. DOI: 10.1016/j.aqpro.2016.07.013.
- Swastawati, F., Susanto, E., Cahyono, B., & Trilaksono, W.A. (2012). Sensory Evaluation and Chemical Characteristics of Smoked Stingray (*Dasyatis Blekeery*) Processed by Using Two Different Liquid Smoke. *International Journal of Bioscience, Biochemistry and Bioinformatics*, (November 2016), 212–216. DOI: 10.7763/ijbbb.2012.v2.103.
- Tahsin, K.N., Soad, A.R., Ali, A.M., & Moury, I.J. (2017). A Review on the Techniques for Quality Assurance of Fish and Fish Products. *International Journal of Advanced Research in Science and Engineering*, 4, 4190–4206.
- Timberg, L., Koppel, K., Kuldjärv, R., & Paalme, T. (2011). Sensory and chemical properties of Baltic sprat (*Sprattus sprattus balticus*) and Baltic herring (*Clupea harengus membras*) in different catching seasons. *Agronomy Research*, 9((Special Issue II), 489–494.
- Timberg, L., Koppel, K., Kuldjärv, R., & Paalme, T. (2014). Ripening and sensory properties of spice-cured sprats and sensory properties development. *Journal of Aquatic Food Product Technology*, 23(2), 129–145. DOI: 10.1080/10498850.2012.700003.
- Toledo, R.T. (2008). Wood Smoke Components and Functional Properties. In: D.E. Kramer and L. Brown (eds.), *International Smoked Seafood Conference Proceedings*. Alaska Sea Grant College Program, Fairbanks, pp. 55–61. DOI: 10.4027/isscp.2008.12.
- Usydus, Z., Szlifier-Richert, J., & Adamczyk, M. (2012). Variations in proximate composition and fatty acid profiles of Baltic sprat (*Sprattus sprattus balticus*). *Food Chemistry*, 130(1), 97–103. DOI: 10.1016/j.foodchem.2011.07.003.

- Varlet, V., Prost, C., & Serot, T. (2007). Volatile aldehydes in smoked fish: Analysis methods, occurrence and mechanisms of formation. *Food Chemistry*, 105(4), 1536–1556. DOI: 10.1016/j.foodchem.2007.03.041.
- Wu, L., Pu, H., & Sun, D.W. (2019). Novel techniques for evaluating freshness quality attributes of fish: A review of recent developments. *Trends in Food Science and Technology*, 83(July 2018), 259–273. DOI: 10.1016/j.tifs.2018.12.002.
- Yanar, Y., Çelik, M., & Akamca, E. (2006). Effects of brine concentration on shelf-life of hot-smoked tilapia (*Oreochromis niloticus*) stored at 4 °C. *Food Chemistry*, 97(2), 244–247. DOI: 10.1016/j.foodchem.2005.03.043.
- Zakipour Rahimabadi, E., & Faralizadeh, S. (2016). Fatty acid composition of fresh and smoked Black and Caspian Sea sprat, *Clupeonella cultriventris* (Nordmann, 1840) treated with different salt composition. *Caspian Journal of Environmental Sciences*, 14(2), 117–124.
- Zugarramurdi, A., Parin, M.A., Gadaleta, L., Carrizo, G., & Lupin, H.M. (2004). The effect of improving raw material quality on product quality and operating costs: A comparative study for lean and fatty fish. *Food Control*, 15(7), 503–509. DOI: 10.1016/j.foodcont.2003.08.001.

CATTLE (*BOS TAURUS*) ENDOMETRIUM MORPHOLOGY ON THE SEVENTH DAY OF THE ESTROUS CYCLE

*Olga Ponomarjova¹, Ilga Sematovica¹, Inga Piginka-Vjaceslavova², Aida Vanaga¹

¹Latvia University of Life Sciences and Technologies, Latvia

²Institute of Food Safety Health and Environment BIOR, Latvia

*Corresponding author's email: olga.ponomarjova@llu.lv

Abstract

The aim of our study was to describe the histopathological and cytological characteristic of the cow endometrium on the seventh day of the estrous cycle. In this study, 11 different breeds' dairy cows (78.18 ± 37.46 months old, in 3.6 ± 2.17 lactation, the mean body condition score 3.4 ± 0.72 (5 points scale)) from Research and Study farm 'Vecauce' were selected. All cows were more than 210 days postpartum. Overall health and reproductive tract examination was performed, progesterone (P4) and estradiol (E2) concentration in blood serum were established and the biopsy and cytology samples of endometrium were taken. Mean E2 concentration was 14.92 ± 7.92 pg mL⁻¹, mean P4 concentration was 13.64 ± 9.44 nmol L⁻¹. The mean percentage in the cytology slides was established: epithelial cells $89 \pm 9\%$, polymorphonuclear leukocytes (PMN) $6 \pm 5\%$. Cytological subclinical endometritis (SE) was confirmed in 5 cows. Histopathological findings (out of 22 samples): endometrium stromal edema in 14, hemosiderin and hemosiderophages in 8, supranuclear vacuolization in 12, pseudodecidual reaction in 12 samples. No subnuclear vacuolization and mitosis in the glandular epithelium were detected. Histopathological examination did not reveal SE. Morphology between the uterine horns with and without corpus luteum (CL) and between cows with serum P4 level higher than 15 nmol L⁻¹ and lower than 15 nmol L⁻¹ were not statistically different ($p > 0.05$). In conclusion, histopathological examination is more reliable diagnostic method for SE. Future investigation should be performed to establish cut-off values for the diagnosis of SE in cows more than 210 days postpartum.

Key words: cattle endometrium, cytology, histopathology, estrous cycle.

Introduction

According to Agricultural Data Centre Republic of Latvia, the number of dairy cows in Latvia since 2010–2015 decreased by 0.1%, but since 2015–2020 it decreased by 16.6%. However, productivity has increased by 31% in the last 10 years. An increasingly important issue is not only the reproductive health of dairy cows in general, but also the reproduction of high-yielding and genetically valuable cows. For this reason, assisted reproduction techniques are being introduced in Latvia within last years – various synchronization protocols, use of sex-sorted sperm, multiple ovulation (MO) and embryo transfer (ET), oocyte aspiration and fertilization in vitro.

On the seventh day of the estrous cycle, the embryo enters in to the uterine horn and contacts to the endometrium. In the process of MO and ET in cattle the embryos are collected and transferred to the recipients uterus horn ipsilateral to CL or could be cryopreserved. There are many factors which affect successful ET process, such as the health of the endometrium in donors and recipients, quality of the embryos, fresh or frozen embryo transfer, serum P4 concentration during the luteal phase of the reproductive cycle and others. The common reasons of unsuccessful ET process were described in previous studies, such as the subclinical endometritis (SE) and endometritis and low circulating P4 concentration (Jimenez-Krassel *et al.*, 2009; Pascottini *et al.*, 2017; Estrada-Cortés *et al.*, 2019). Histopathological examination of the endometrium biopsy samples and exfoliative cytological examination of the endometrium are the

gold standard for evaluation of the uterine condition (Benbia *et al.*, 2013). For this, the seventh day of the estrous cycle is the area of the interest in our study.

The aim of our study was to describe the histopathological and cytological characteristic of the cow endometrium on the seventh day of the estrous cycle in relation to steroid hormones (E2 and P4). The objectives of the study were to detect and evaluate the morphological findings in the cow endometrium between uterine horns depending on the presence of the CL in the ovary and serum P4 level on the seventh day of the oestrus cycle.

Materials and Methods

Eleven Research and Study farm 'Vecauce' dairy cows (eight Holstein and three Latvian Brown cows) were selected for this study during the period from January 2019 until January 2020. Cows were 78.2 ± 37.46 months old (min. 37, max. 158 months), they were in 3.6 ± 2.17 lactation (min. 1.0, max. 7.0 lactation) and the mean body condition score (BCS) was 3.4 ± 0.72 (5 points scale). Cows were more than 210 days postpartum. Cows were synchronized with Ovarelin (Gonadorelin, Ceva Sante Animale, France) injections $50 \mu\text{g ml}^{-1}$ 2 ml i.m. (0, 10 day) and Enzaprost (Dinoprost, Ceva Sante Animale, France) 5 mg ml^{-1} 5 ml i.m. (7, 8 day).

Overall health and reproductive tract examination was performed on the seventh day of the estrous cycle. Uterus, uterine horns and ovarian structures (CL and follicles) were assessed by rectal palpation and transrectal reproductive ultrasonography (Easi-Scan,

BCF Technology). Blood samples were collected from tail vein to establish P4 and E2 concentration. Analyses of P4 and E2 were carried out in the accredited laboratory of the Institute of Food Safety, Animal Health and Environment 'BIOR', Latvia (No. LVS EN ISO/IEC 17025:2017). Before endometrial cytology and biopsy samples were taken using cytobrushes (Mekalasi, SAXO, Finland), epidural anesthesia was provided using Procamidol 20 mg ml⁻¹ (Procaini hydrochloridum, Richter Pharma AG, Austria) 2.0–4.0 ml. Endometrial cytology samples were obtained under rectal guidance. The cytobrush, placed in a stainless steel tube, was inserted into the uterine lumen through the uterine cervix. Then the brush was released in the uterine lumen and rotated against the uterine body dorsal wall. Slides for cytological examination were prepared by rolling the cytobrush onto a clean glass slide. Cytology slides were stained with Diff-Quick stain (Sysmex, Japan). Two slides from each cow were prepared for examination. Two hundred cells on each slide were differentiated (light microscope Nikon Eclipse 80i, 400× magnification) and the percentage of PMN was assessed (Melcher, Prunner, & Drillich, 2014). The threshold level of PMN for diagnosis of SE was set at 5% (Egberts *et al.*, 2016). A total of 22 slides was investigated by doctoral student in the laboratory of Latvia University of Life Sciences and Technologies Small Animal Veterinary clinic in collaboration with experience laboratory staff.

Endometrial biopsy samples using the endometrial biopsy instrument (Denmark, 'Kruise') were obtained. The biopsy instrument was introduced into the uterine lumen under rectal guidance, and biopsies were taken from the ventral surface of the right and left uterine horn dorsal wall.

The total number of histopathological samples was 22 samples. The samples were prepared for further histopathological examination: fixed in 10% neutral formalin and stored for 24 hours in room temperature. The Leica TP 1020 tissue processor for dehydration and fat removal was used. Then the samples were embedded in the paraffin blocks. The samples were sectioned at 5-µm thickness and were put on the slides. The drying process was performed +58 °C for 20 min in Binder 140KB 53 thermostat. Samples were stained with haematoxylin and eosin (H/E) and light microscope Zeiss was used for evaluation of endometrium morphology. Histopathological examination was performed at the Institute of Food Safety, Animal Health and Environment 'BIOR', Latvia.

In each sample the following histopathological characteristic principles were assessed: 1) size of the glandular epithelium (3 point system: 1– small with strong eosinophil cytoplasm and small amount

of cytoplasm; 2– medium with light eosinophil cytoplasm and medium amount of cytoplasm; 3– large with very light cytoplasm and large amount of cytoplasm); 2) vacuolization of glandular epithelium cytoplasm (presence of supranuclear or subnuclear vacuoles); 3) mitosis in the glandular epithelium; 4) pseudodecidual reaction in glandular epithelium; 5) secret of glandular epithelium in the glands lumen; 6) endometrium stromal edema; 7) hemosiderin in the endometrium; 8) inflammatory cells in endometrium in the glands area.

Morphological parameters of endometrium were compared between uterine horns with CL and without CL presence in ovaries; between cows with high serum P4 level (> 15 nmol L⁻¹) and low serum P4 level (<15 nmol L⁻¹) (Pascottini *et al.*, 2016; Benbia *et al.*, 2017).

Data are expressed as the mean ± SD, percentage and independent samples t-tests were performed for statistical analysis considering the significance level of p<0.05 using IBM SPSS Statistics 21 software.

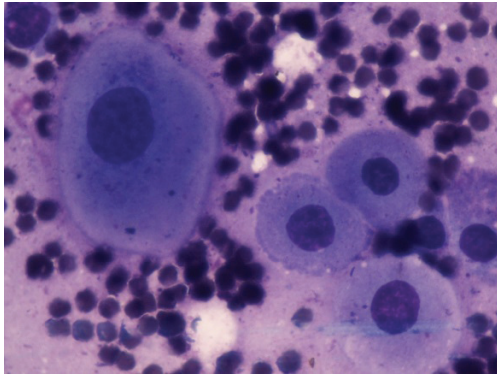
Results and Discussion

All 11 cows selected for this study were clinically healthy. Examination of reproductive tract revealed that 10 cows had at least one CL and one follicle in the ovaries and one cow had not CL at all, only few follicles.

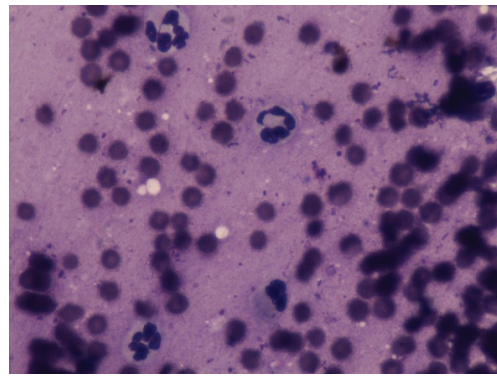
Mean E2 concentration was 14.92 ± 7.92 pg mL⁻¹, (min. 9, max 31.73). Cows without CL in the ovaries had higher E2 concentration in blood serum (31.73 pg mL⁻¹,) than cows with CL presence in the ovaries (13.24 ± 5.78 pg mL⁻¹, min. 9, max. 25.84).

Mean P4 concentration was 13.64 ± 9.44 nmol L⁻¹ (min 1.05, max. 28.11). Two cows had P4 concentration less than 1.2 nmol L⁻¹. It proves a very low CL functional activity. One cow without CL had low P4 concentration (4.83 nmol L⁻¹) in blood serum. This can be explained by the effect of the dominant follicle producing E2 during first follicular wave (Muir, 2019).

The mean percentage of epithelial cells (Figure 1a) in the cytology slides was 89 ± 9% (min. 73, max. 98), the mean percentage of the PMN (Figure 1.b.) was 6 ± 5% (min. 1, max. 19). Eosinophil leukocytes were detected in two samples (n=11), one and two cells respectively. The lymphocytes were in eight samples, the mean percentage was 4 ± 5% (min. 0, max.15). The monocytes were detected in two samples, one and two cells respectively. In 5 cytology samples the PMN threshold of 5% was exceeded, 5 cows (n=11; mean 6 ± 5%, min. 1, max 19) have had elevated percentage of PMN and diagnosis of subclinical endometritis (SE) was confirmed. In two samples eosinophils were detected in the slides (1 and 2%). In the previous study, the prevalence of SE was 12.7% diagnosed by



1a. Epithelial cells (arrow), 400× magnification.



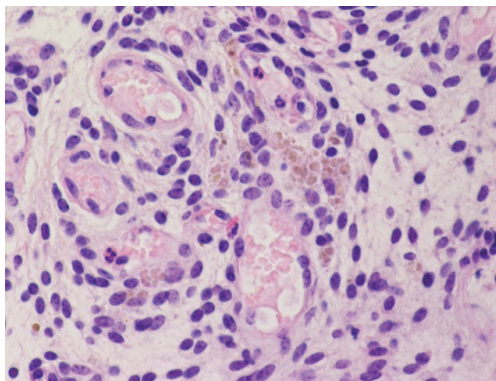
1b. PMN (arrow), 400× magnification.

Figure 1. Exfoliative cytology of cow endometrium on the seventh day of the estrous cycle.

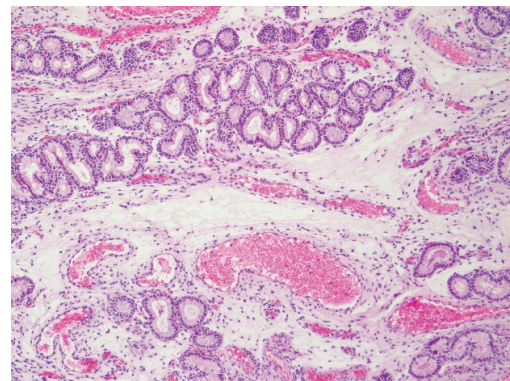
cytological examination, which was not consistent with our study result (Pothmann *et al.*, 2015).

In 22 biopsies samples (11 from the left and 11 from the right uterine horns) performed histopathological examination revealed the following:

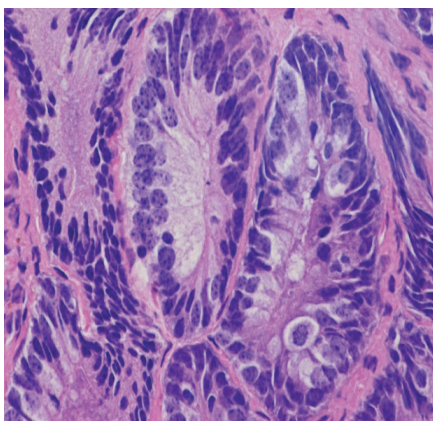
endometrium stromal edema (Figure 2b) was in 14 samples, hemosiderin and hemosiderophages – in 8, supranuclear vacuolization (Figure 2d) – in 12, subnuclear vacuolization in none of samples, pseudodecidual reaction (Figure 2c) – in 6, mitosis



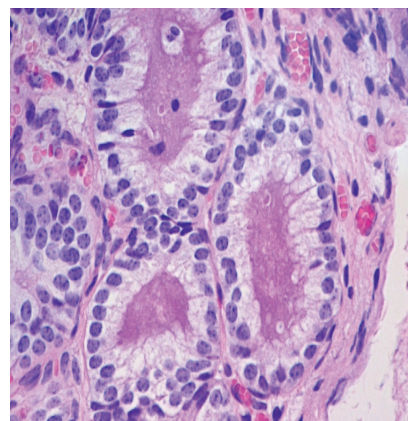
2a. Inflammation cell in endometrium stroma. Red arrow – neutrophil leucocyte, black arrow – eosinophil leucocyte, green arrow – hemosiderophage, 600× magnification.



2b. Endometrium edema. Black arrow – fluid in stroma of endometrium, 600× magnification.



2c. Pseudodecidual reaction. Black arrow – glandular epithelium cell is large, nucleus of cell is large and pale with visible nucleoli. 600× magnification.



2d. Vacuolization of glandular epithelium cytoplasm. Black arrow – supranuclear vacuoles, red arrow – secret of glandular epithelium in the gland lumen. 600× magnification.

Figure 2. Histopathology of the cow endometrium on the seventh day of the estrous cycle.

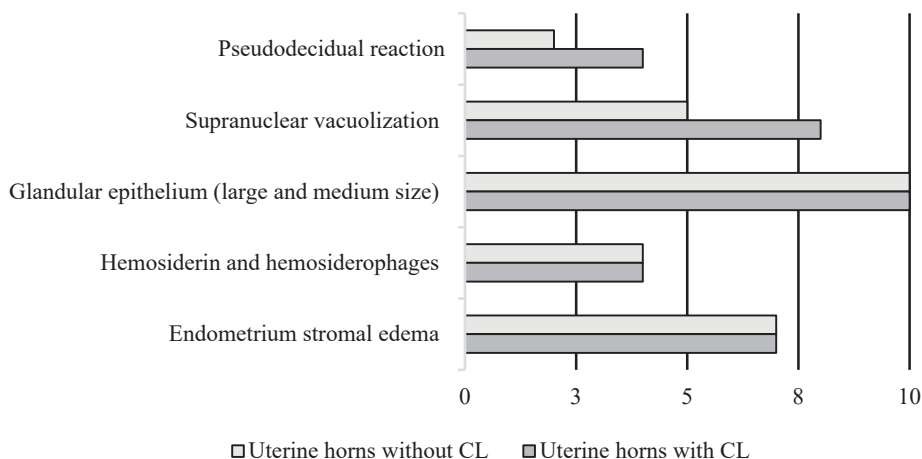


Figure 3. The morphological findings in the endometrium of the uterine horns between the uterine horns with (n=12) and without CL (n=10).

in the glandular epithelium was found in none of samples. In 20 samples, the glandular epithelium was large and medium size, in 2 samples – small size. In luteal phase, glandular epithelium becomes higher and contains large number of secretion vacuoles. Mitosis in the glandular epithelium and endometrium stromal edema characterize follicular phase (Espejel & Medrano, 2017).

The infiltration of neutrophil leukocytes in the endometrium was not detected in any of samples, the infiltration of eosinophil leukocytes – in 4 samples (Figure 2a). The mean cells count was 0.9 ± 2.65 (min.0, max 11 cells). The infiltration of the mast cells was in 7 samples. The mean cells count was 0.82 ± 0.78 (min. 0, max 4). Presence of inflammatory cells in the endometrium is still under discussion. Eosinophil leukocytes may be present in the stratum compactum of the endometrium and their number is

invariable throughout estrous cycle. The infiltration of neutrophils can be in the endometrium during proestrus, estrus, and metestrus. As well as mast cells can form clusters (5–10 cells) in the stratum compactum in any stage of the estrous cycle (Espejel & Medrano, 2017).

Histopathological results show that no one of these cows had SE or endometritis. Characteristic histopathological features of SE are epithelial degeneration and desquamation in the epithelial lamina and of endometritis – focal or diffuse inflammatory cells infiltration of lymphocytes, plasma cells and PMN in *lamina propria* (Dogan, Sonmez, & Sagirkaya, 2002).

There was no statistically significant difference in the morphological finding in the endometrium between the uterine horns with CL (n=12) and without CL (n=10): endometrium stromal edema $p=0.59$,

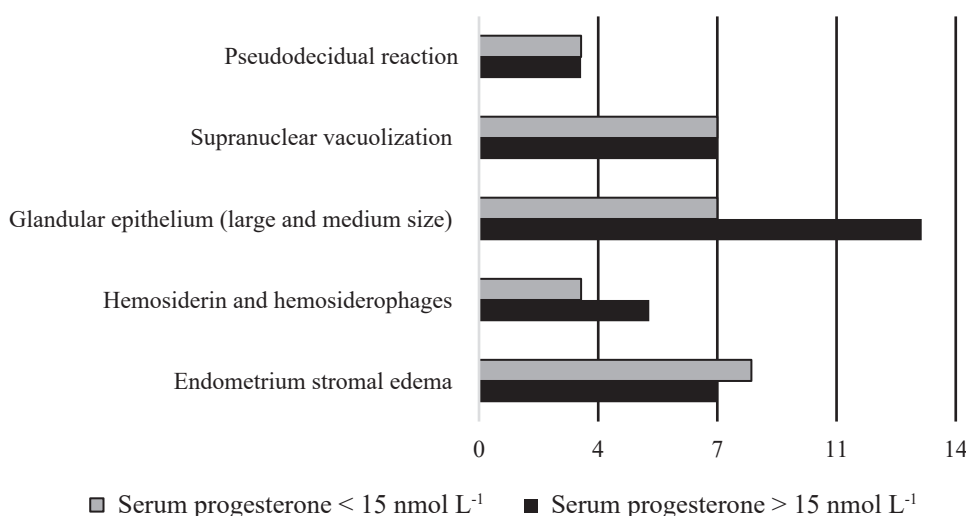


Figure 4. The morphological findings in the endometrium of the uterine horns between cows with serum progesterone level $>15 \text{ nmol L}^{-1}$ (n=13) and with serum progesterone $<15 \text{ nmol L}^{-1}$ (n=10).

hemosiderin and hemosiderophages $p=0.76$, size of the glandular epithelium $p=0.34$, supranuclear vacuolization $p=0.45$, pseudodecidual reaction $p=0.50$; $p>0.05$ (Figure 3). The recommendation for successful embryo transfer is to place the embryo into the uterine horn with CL in the ipsilateral ovary. In the previous study, differences in gene expression between the endometrium of uterine horns ipsilateral and contralateral to the CL in cattle were defined, but the site of embryo transfer did not affect pregnancy establishment in cattle (Sanchez *et al.*, 2018). Our study showed that morphological finding in the endometrium was similar between uterine horns with and without CL in ovary.

There was no statistically significant difference in the morphological finding in the endometrium of the uterine horns between cows with serum P4 level $> 15 \text{ nmol L}^{-1}$ ($n=13$) and with serum P4 $< 15 \text{ nmol L}^{-1}$ ($n=10$): endometrium stromal edema $p=0.27$, hemosiderin and hemosiderophages $p=0.69$, size of the glandular epithelium $p=0.08$, supranuclear vacuolization $p=0.45$, pseudodecidual reaction $p=0.73$; $p>0.05$ (Figure 4). In the previous study authors did not define correlation between endometrium morphology and serum P4 level concentration in cattle blood between the 5th and 8th estrous day similar to the results of our study (Wang *et al.*, 2007).

The histopathological examination results did not confirm diagnosis of SE. It could be explained, because of the threshold for the diagnosis of SE is still under discussion and varied between 5% and 18%, depending on the days postpartum (Wagener, Gabler, & Drillich, 2017). The cytology has a lower

sensitivity to diagnose inflammatory reactions in the endometrium of dairy cows in comparison to histopathology (Pascottini *et al.*, 2016). In the later postpartum period (30–60 days), the threshold for SE was 10% (Cheong *et al.*, 2011) and 5% (Gilbert *et al.*, 2005; Madoz *et al.*, 2013). In our study cows were >210 days postpartum, so it is possible that it was the reason of SE prevalence in 5 cows ($n=11$). Some authors considered that cut-off values for the diagnosis were 18% (Kasimanickam *et al.*, 2004). If cut-off for diagnosis of SE was accepted 18%, in our study one cow had SE ($n=11$).

Conclusions

The main morphological findings in the cow endometrium on the seventh day of the estrous cycle were endometrial glands activity and endometrium stromal edema without significant differences between the uterine horns with and without CL in the ipsilateral ovary and between cows with high and low serum P4 level. Despite endometrial cytology is considered to be the accurate method to diagnose SE, histopathological examination is more reliable diagnostic method for SE. Future investigations should be done, to improved cut-off values for cytological examination for the diagnosis of SE in cows more than 60 days postpartum.

Acknowledgments

We acknowledge the ERAF project No. 1.1.1.1/16/A/025 ‘Preservation of bovine genetic resources in Latvia using embryo transfer and related biotechnologies’ for study’s financial support.

References

- Benbia, S., Yahia, M., Letron, I.R., & Benounne, O. (2017). Endometrial cells morphology depending on estrous cycle and histologic layers in cows: morphometric study. *Global Veterinaria* 18(1), 68–73. DOI: 10.5829/idosi.gv.2017.68.73.
- Cheong, S.H., Nydam, D.V., Galvao, K.N., Crosier, B.M., & Gilbert, R.O. (2011). Cow-level and herd-level risk factors for subclinical endometritis in lactating Holstein cows. *J Dairy Sci* 94(2), 762–70. DOI: 10.3168/jds.2010-3439.
- Dogan, I., Sonmez, G., & Sagirkaya, H. (2002). Histopathological investigation of endometrium in repeat breeder cows. *Indian Journal of Animal Sciences* 72(3), 223–226. Retrieved March 17, 2020, from <https://www.researchgate.net/publication/297910246>.
- Espejel, M.C., & Medrano, A. (2017). Histological cyclic endometrial changes in dairy cows: An Overview. *Dairy and Vet Sci J* 2(1), 555577. DOI: 10.19080/JDVS.2017.02.555577.
- Estrada-Cortés, E., Ortiz, W.G., Chebel, R.C., Jannaman, E.A., Moss, J.I., Cavallari de Castro, F., Zolini, A. M., Staples, C.R., & Hansen, P.J. (2019). Embryo and cow factors affecting pregnancy per embryo transfer for multiple-service, lactating Holstein recipients. *Translational Animal Science* 3(1), 60–65. DOI: 10.1093/tas/txz009.
- Egberts, J., Detterer, J., Park, A., & Meinecke-Tillmann, S. (2016). Exfoliative endometrial cytology in embryo donor cows – comparison of sampling localizations for the diagnosis of subclinical endometritis. *Veterinary Sciences* 3(4), 35. DOI: 10.3390/vetsci3040035.
- Gilbert, R.O., Shin, S.T., Guard, C.L., Erb, H.N., & Frajblat, M. (2005). Prevalence of endometritis and its effects on reproductive performance of dairy cows. *Theriogenology*.64(9), 1879–88. DOI: 10.1016/j.theriogenology.2005.04.022.

- Jimenez-Krassel, F., Folger, J.K., Ireland, J.L.H., Smith, G.W., Hou, X., Davis, J.S., Lonergan, P., Evans, A. C.O., & Ireland, J.J. (2009). Evidence that high variation in ovarian reserves of healthy young adults has a negative impact on the corpus luteum and endometrium during estrous cycles in cattle. *Biology of Reproduction* 80 (6), 1272–1281. DOI: 10.1095/biolreprod.108.075093.
- Kasimanickam, R., Duffield, T.F., Foster, R.A., Gartley, C.J., Leslie, K.E., Walton, J.S., & Johnson, W.H. (2004). Endometrial cytology and ultrasonography for the detection of subclinical endometritis in postpartum dairy cows. *Theriogenology* 62(1–2), 9–23. DOI: 10.1016/j.theriogenology.2003.03.001.
- Madoz, L.V., Giuliadori, M.J., Jaureguiberry, M., Plontzke, J., Drillich, M., & de la Sota, R.L. (2013). The relationship between endometrial cytology during estrous cycle and cutoff points for the diagnosis of subclinical endometritis in grazing dairy cows. *Journal of Dairy Science* 96(7), 4333–4339. DOI: 10.3168/jds.2012-6269.
- Melcher, Y., Prunner, I., & Drillich, M. (2014). Degree of variation and reproducibility of different methods for the diagnosis of subclinical endometritis. *Theriogenology* 82(1), 57–63. DOI: 10.1016/j.theriogenology.2014.03.003.
- Muira, R. (2019). Physiological characteristics and effects on fertility of the first follicular wave dominant follicle in cattle. *Journal of Reproduction and Development* 65(4), 289–295. DOI: 10.1262/jrd.2019-027.
- Pascottini, O.B., Hostens, M., Dini, P., Vandepitte, J., Ducatelle, R., & Opsomer, G. (2016). Comparison between cytology and histopathology to evaluate subclinical endometritis in dairy cows. *Theriogenology*, 86(6), 1550–1556. DOI: 10.1016/j.theriogenology.2016.05.014.
- Pascottini, O.B., Hostens, M., Sys, P., Vercauteren, P., & Opsomer, G. (2017). Risk factors associated with cytological endometritis diagnosed at artificial insemination in dairy cows. *Theriogenology* 92, 1–5. DOI: 10.1016/j.theriogenology.2017.01.004.
- Pothmann, H., Prunner, I., Wagener, K., Jaureguiberry, M., de la Sota, R., L., Erber, R., Aurich, C., Ehling-Schulz, M., & Drillich, M. (2015). The prevalence of subclinical endometritis and intrauterine infections in repeat breeder cows. *Theriogenology* 83(8), 1249–1253. DOI: 10.1016/j.theriogenology.2015.01.013.
- Sánchez, J.M., Passaro, C., Forde, N., Browne, J.A., Behura, S.K., Fernández-Fuertes, B., Mathew, D.J., Kelly, A.K., Butler, S.T., Spencer, T.E., & Lonergan, P. (2018). Do differences in the endometrial transcriptome between uterine horns ipsilateral and contralateral to the corpus luteum influence conceptus growth to day 14 in cattle? *Biology of Reproduction*. 100(1), 86–100. DOI: 10.1093/biolre/ioy185.
- Wagener, K., Gabler, C., & Drillich, M. (2017). A review of the ongoing discussion about definition, diagnosis and pathomechanism of subclinical endometritis in dairy cows. *Theriogenology* 94, 21–30. DOI: 10.1016/j.theriogenology.2017.02.005.
- Wang, C.K., Robinson, R.S., Flint, A.P.F., & Mann, G.E. (2007). Quantitative analysis of changes in endometrial gland morphology during the bovine oestrous cycle and their association with progesterone levels. *Reproduction* 134(2), 365–371. DOI: 10.1530/REP-06-0133.

LEGAL AND MANAGERIAL SOLUTIONS OF PUBLIC SECTOR AUTHORITIES FOR PRESERVING ECOSYSTEM SERVICES OF THE LAKES

*Lina Marcinkevičiūtė, Jolanta Vilkevičiūtė, Jan Žukovskis

Vytautas Magnus University, Lithuania

*Corresponding author's email: lina.marcinkeviciute@vdu.lt

Abstract

Although the problem of ecosystem diversity loss is of a global nature, the measures to solve it must be implemented at the national level. As a member of the European Union, Lithuania needs to have a clear position regarding the application of proposed socio-economic measures. The problems of lake ecosystem utilisation analysed in the article are based on the scientific knowledge which complies with the specifics of regional natural environment. The aim of the article is to systematize scientific knowledge about modern lake ecosystem services by explaining the fundamental adaptation patterns of ecosystems and their components. The article provides a complex assessment of the services provided by lake ecosystems, reveals management problems related to optimization of the use of lake ecosystems, presents recommendations on the improvement of legislation related to lake ecosystem services, regulations for protected areas, management plans, etc.

Key words: ecosystem services, lakes, management, public sector.

Introduction

It is generally assumed that the majority of research papers which analyse the use of lakes for various agricultural activities are related to the impact of agriculture on the quality of water in lakes. Generally, researchers focus on the analysis of specific lakes and the impact of agriculture on them. Eutrophication and concentration of certain chemicals (phosphorus, nitrates, etc.) in lake water are investigated (Nakano *et al.*, 2008; Dirbock *et al.*, 2017; Scholes, 2016; Downing & Heathcote, 2012). There are not many works that analyse the utilisation of lakes in the socio-economic field. The majority of research papers mainly describe only the industrial impact on lake ecosystems (Holopainen *et al.*, 2003) and the use of lakes in the energy sector.

Research papers that focus on the analysis of lakeside landscape should also be mentioned because it is also relevant in the use of lakes. Other works investigate the change of lakeside landscape within a certain period of time using maps and satellite images (Ke *et al.*, 2018; Smith, 2014). Additionally, it is worth highlighting publications by foreign researchers related to the determination of the value of lake area, which affects the sale price of residential houses and land lots as well as the rent prices of residential houses (Lake Classification..., 1996).

The aim of the research - to analyze public sector management solutions in different countries to preserve lakes ecosystem services and to provide socio-economic insights on the nature conservation policy.

Materials and Methods

The following data collection and analysis methods were used for the study: 1. Document Analysis. Taking into account the object of scientific research (ecosystem services of lakes), the aims and objectives of the research, this method is considered the most important method

of data collection (obtaining). Sources of data to be collected: national, European Union and international legislation, scientific books and magazines, press publications; official statistics (statistics provided by the Department of Statistics, municipalities, protected areas); official government publications; documents from private, public, professional and other non-governmental organizations. 2. Qualitative content analysis. The analysis material consisted of text obtained using various data collection methods (written surveys, interviews, document analysis, etc.). The text was worked on as the main analytical material and analyzed only in a specific context. The results of the analysis were used to substantiate the results of the analysis. The above analysis was carried out on the basis of methodologically based principles of analysis: 1) reading of text and separation of main aspects (phrases, sentences, words, etc.) and categories; 2) breakdown of categories into elements; 3) subdivision of meaningful elements into sub-categories; 4) including categories in the context of the research phenomenon. 3. Comparative analysis. It allowed researchers to discover differences and similarities not only in the practice of phenomena (eg ecosystem (biodiversity) preservation) in Lithuania, but also in "good practice" examples in different countries. Using this method, it was imperative to deepen / empathize with another cultural perspective to learn to understand the thinking processes of other cultures and see it from the inside, not from the outside (through the eyes of the insider), as well as to evaluate the research phenomena taking place in their country in the eyes of an impartial observer.

Results and Discussion

In scientific literature, the concept of *lake ecosystems* is used to describe the functioning of lakes (flows of energy, nutrients) and sometimes is associated with the benefit to people from the

properties and the processes of ecosystems (food production, sewage storages). *The function of lake ecosystems* is a set of natural processes and components which satisfy human needs without harming lakes (de Groot, 1992). The most important aspects of the environmental protection function of lakes are as follows: 1) regulation (this function more or less regulates the possibilities of lake use in all other areas, i.e. recreation, fishing, communication, etc.; 2) maintenance of living environment stability (this function aims to maintain typical habitat for lake flora and fauna and to ensure their constant abundance and diversity. This is achieved through water quality control and supervision of lake resource usage (de Groot, 2002).

To summarise the definitions given in the scientific literature, *functional usage of lakes* can be described as the use of lake resources for various human needs and maintenance of stability of ecosystems and their services. It has been observed (Daubarienė, 2012) that the majority of studies on lake functions focus on the use of lakes to satisfy human interests. There are almost no studies in which the possibilities of protecting natural ecosystems are attributed to the functions of lakes, although a lake, as a natural ecosystem, performs this as its most important function. The usage of lakes needs to be balanced and coordinated not only for domestic, agricultural, industrial, or recreational purposes, but also for environmental needs. Balancing economic and environmental priorities and meeting the needs of different interest

groups can only be achieved through a complex or sustainable management of water resources.

Proper use of lakes is essential to the preservation of lake ecosystems. Misuse of lakes can lead to increased eutrophication processes and extinction of valuable fish or bird species. As a result of improperly selected ecosystem services, lakes can often lose their aesthetic image and value. Essential functions of a lake ecosystem are described in Table 1 below.

It is often impossible to separate one function of a lake ecosystem from another because some activities can be carried out by performing several functions at once. In lakes, it is difficult to separate recreation from transport (the latter is strongly connected to water tourism), industry from energy, and agriculture from domestic use (when performing these functions, the majority of activities are almost identical) (Global., 2018; Hung, 2005; Scholte, 2016). Notably, resting by the lakeside, swimming, recreational fishing, and sailing on small vessels are currently the most popular uses of lake ecosystem services. *The implementation of these services often does not require huge investments; however, a very clear and logical management framework is needed, which would determine the possibilities and limits of the development of specific lake usage areas.* The importance of ecosystem services for human welfare is certainly unquestionable but has not been fully assessed yet. It has been estimated that Natura 2000, a network of protected sites, generates EUR 200–300 billion annually, while its management costs are only

Table 1

Usage functions of a lake ecosystem
(Beklioglu, 2016; Cunning, 2014; Hamilton, 2013; Millenium..., 2005)

Usage function	Description
<i>Main usage functions</i>	
Nature conservation	Protection of ecosystems (conservation of fauna and flora habitats, promotion of bio-diversity, conservation of habitats for migrating animals, regulation of water, air and microclimate.
Recreation	Resting by the lakesides (camping), swimming, recreational fishery, fishing of crayfish and molluscs, observation of living nature, organization of artistic and religious events, supply of materials for research and awareness-raising.
Transport	Sailing by self-propelled and not-self-propelled vessels
Agriculture and domestic needs	Irrigation and watering (water for fields of crops, kitchen gardens, pastures, recreational places (parks, etc.)) Livestock watering and feeding (forage for livestock: fish, crayfish, molluscs, etc.) Wastewater discharge
<i>Additional usage functions</i>	
Commercial fishing	Fishing, fisheries
Commercial fishing of crayfish and molluscs	Cultivation and sales of crayfish and molluscs
Industry and energy	Water for production, cleaning, cooling, energy generation, etc.

Table 2

Environmental Performance Index Results, 2018 (Environmental..., 2018)

Country	EPI Ranking	Environmental Performance Index	Environmental Health	Ecosystem Vitality
Switzerland	1	87.42	93.57	83.32
France	2	83.95	95.71	76.11
Denmark	3	81.60	98.20	70.53
Malta	4 ...	80.90	93.80	72.30
Lithuania	29 ...	69.33	72.57	67.18
Bangladesh	179	29.56	11.96	41.29

EUR 6 billion a year (about EUR 15 billion of the European agricultural production depends on insect pollinators and about EUR 4.4 billion jobs in the EU directly depend on ‘healthy’ ecosystems). Such fundamental knowledge, as well as socio-economic assessment of ecosystem services, are necessary for effective environmental protection in order to ensure public welfare.

After the scientific literature analysis, it was found that the Environmental Quality Index of Yale and Columbia Universities was used to assess Lithuania’s environmental situation. The index is made up of 9 different environmental indicators and areas of activity, with a score between 0 and 100 for each indicator. According to the data of Lithuania, Lithuania ranks 29th out of 179 countries included in the index (estimate about 69.33) Table 2.

Lithuania’s highest performance is dominated by environmental protection (72.57) and ecosystem conservation (67.18). The worst rated is the performance of Lithuanian companies, the public

and the government in the areas of fisheries, forestry and agriculture in a sustainable way Table 3 (Environmental Performance Index, 2018).

It should be emphasized that a lot of state organizations and institutions participate in the management of water resources (including lakes) in Lithuania. The Ministry of Environment is the main authority responsible for the management of water resources in the country. Also noteworthy are Joint Research Centre, Lithuanian Geological Survey, Hydrometeorological Service and the Department of Fish Resources. Regional Environmental Protection Departments established in the administrative centers of Lithuania are responsible for the implementation of environmental legislation and policies. Some water management functions are delegated to the Ministry of Health and its subordinate institutions (State Hygiene Inspectorate, Public Health Center, National Nutrition Center). Territorial management of water resources is also conducted in districts and municipalities. Sometimes even the long-term managers of

Table 3

Environmental Performance Index Results (Issue Categories), 2018 (Environmental..., 2018)

Issue Categories	Country and Rank			
	Switzerland (1)	France (2)...	Lithuania (29)...	Bangladesh (179)
Environmental Health	93.57	95.71	72.57	77.96
Air Quality	91.06	95.97	77.97	4.12
Water & Sanitation	99.99	97.22	58.51	28.47
Heavy Metals	87.77	83.29	86.63	14.72
Ecosystem Vitality	83.32	76.11	67.18	41.29
Biodiversity & Habitat	84.20	96.25	93.83	53.58
Forests	47.40	25.08	7.75	12.13
Fisheries	-	57.71	57.83	66.86
Climate & Energy	90.55	70.46	62.46	46.95
Air Pollution	98.70	96.82	59.73	40.22
<i>Water Resources</i>	<i>99.67</i>	<i>95.56</i>	<i>93.46</i>	<i>0.00</i>
Agriculture	43.87	67.77	62.01	37.82

environmental organizations find it difficult to keep up with the editions of legislation projects and proposals (related to environmental protection), or with the functions performed by the aforementioned institutions. The analysis of the prepared documents on state development and branch strategies, regional policy, and municipal strategic development (related to environmental protection) shows that there is a confusion between numerous priorities and initiatives. Strategic development plans ranging from 85 to 200 pages can be found in each municipality. These plans include a lot of tasks, which vary from the renovation of water and heating networks to the maintenance of tourist attractions and provision of bicycle paths. It may be noted that, when the authorities are lost in the ‘overabundance of priorities’, the society is also confused about the systems of values and goals (the documents comply with the ‘fill in’ requirements of the EU, but their practical applicability in a specific territory is forgotten).

Protecting natural water resources is one of the most important tasks today, not only in the European Union, but also in the world. The world is taking not only political but also legal measures to ensure the protection of natural water and biodiversity and our right to clean water resources.

European Union policy has established two very important and main legal frameworks for the protection and management of marine and freshwater resources in the EU – the Marine Strategy Framework Directive and Water Framework Directive. The main target of Water Framework Directive is to prevent and reduce pollution,

promote sustainable water use in everyday life, protect and improve the aquatic environment and mitigate the effects of floods and droughts in EU countries. In the EU we have more targeted legal acts (directives) related to water resources protection: the Floods Directive, the Nitrates Directive, the Bathing Water Directive, the Groundwater Directive, the Drinking Water Directive, the Urban Waste Water Treatment Directive and the Environmental Quality Standards Directive (Water protection and management, 2018). The requirements of these legal acts are implemented in the national legislation of the Member States. Member States also regulate the protection and use of water resources in their national legislation by programmes, strategies, action plans and laws. It should be noted that the protection of natural water resources is regulated not only by direct legal regulation of the water resources, but also of other legal acts, which ensure environmental protection, pollution reduction and long-term state members strategies oriented towards sustainable use of natural resources. The table below provides basic legislation in separate states to ensure legal protection of water resources. Examples of various foreign legal documents governing the supervision of water resources (including the supervision of lakes) are described in Table 4.

It should be noted that each lake’s shores, area, water, flora, fauna, sapropel, etc. can be used for various purposes (Brink, 2013; Caceres, 2015; Delgado, 2015). Every lake is unique and distinctive because of its ecosystem and its services; therefore, it is possible for one lake to be used in just one

Table 4

Examples of foreign legal documents governing the supervision of water resources
(An introduction., 2008; Danish., 2008; Denmark., 2007; du Bray, 2019; Polhill, 2016)

Documents	Goals and Objectives
Italy	
Regulations for water emergencies	To address water crises, providing technical and financial support for emergency measures.
Law 267/19982 (‘Legge Sarno’):	Requires water basin authorities to detect risk areas, set prevention plans and establish regulations to avoid additional risk.
Directive 2007/60/CE implemented in Italy with Decree 152/2006:	Aims to establish a framework for the assessment and management of flood risks, aiming at the reduction of the adverse consequences for human health, the environment, cultural heritage and economic activity associated with floods in the Community.
The Legislative Decree No. 49/2010	Requires flood risk management plans to be established and approved by June 2015 (under implementation).
National Action Plan	To combat drought and desertification includes measures to address water and ground water protection and water efficiency through planning instruments and water protection plans.
National Plan for Biodiversity	Includes measures to address biodiversity protection, including water ecosystems protection.

Documents	Goals and Objectives
Denmark	
Action Plan for the Aquatic Environment III (till 2015)	Contains initiatives for improving the aquatic environment and nature and to reduce agricultural impacts on the aquatic environment and nature.
Water Supply Act (No. 125 of 2017)	To ensure the use and protection of water bodies by implementing a comprehensive planning and following assessment of water supply (quality water supply, environmental protection, conservation of nature, using mineral resources; to coordinate existing water supply for prudent use of water; implementing a planned expansion and operation of adequate and satisfactory quality of water supply; to ensuring quality of drinking water for the protection of human health.
Danish Water Sector Reform Act (2009)	This legal act is regulating municipal water and wastewater utilities as well as private waterworks and requires drinking water and wastewater utilities to collect specific performance parameters, including water loss.
Scotland	
The Water Environment Regulations (2011) and amendments in 2013 and last in the year 2017	This legal act applies regulatory controls over activities which may affect Scotland's water environment.
Water Environment and Water Services (Scotland) Act 2003	This legal act covers protection of rivers, lochs, transitional waters (estuaries), coastal waters groundwater, and groundwater dependent wetlands.
Poland	
Draft National Strategy for Management of Water Resources 2030 (2010)	The strategic goal of implementing an integrated water management system is to provide the population with access to clean and healthy water, and reduce the risks related to floods and droughts.
Water Act (2017)	This legal act regulates water management in accordance with the principle of sustainable development, in particular shaping and protection of water resources, use of waters and management of water resources in Poland.
Lithuania	
The National Sustainable development strategy (2009)	The document sets a long-term objective in the field of Landscape and Biological Diversity 'to preserve landscape and biological diversity, nature and cultural heritage values, promote restoration of damaged natural elements and ensure rational use of landscape and biological diversity'.
Law on protected areas (2011)	The main purpose of the Law: to specify the public relations regarding protected areas, the system of protected areas, the legal basis for the establishment, protection, management and control of protected areas as well as regulates the carrying out of activities therein.
Law on water (2003)	This law regulates the ownership of the internal bodies of water of the Republic of Lithuania, the management, use and protection of their water resources and the rights and obligations of legal and natural persons using internal bodies of water and their resources.
Law on drinking water (2001)	This law establishes the conditions of ensuring the safety and quality of the drinking water.

area and for another one to be utilized for multiple purposes (Reynaud, 2017; Scottish..., 2018). *Factors that are relevant to lake usage are very diverse and may be related to: the morphometric and water mass properties of the lake itself; the lake's geographical position; lake management (ownership) type; anthropogenic activities on the shores of lakes; legal regulation; other factors.* The research has revealed that 80 percent of cultural and active leisure services offered in Lithuania are not adapted for all seasons.

The majority of accommodation homesteads offering accommodation near lakes (85%) work only during the warm season. Alternatively, *parallel business (which would help to reduce the seasonality of ongoing activities) related to the services of lake ecosystem* may be offered, such as: business related to biofuel production (recycling of felled reeds, trees, tree branches or tree falls for biofuel); business related to the extraction and use of sapropel (sludge) (fertilizers and substrates, feed additives for birds and livestock,

etc.); business related to the production of building materials (usage of reeds for roofing, usage of sludge for the production of expanded clay, etc.); business related to bio-humus production, etc., but there is a lack of theoretical or practical information on how to apply these alternatives to their farms or homesteads. Recommendations could be the development of educational activities in the municipality, special seminars with good practice examples (not only in Lithuania, but also in foreign countries), provision of specialized informational material which would not only specify the laws or regulations to be followed, but would also provide a summary of detailed information about possible alternative businesses in order to avoid the seasonality of activity and reduce the unemployment rate.

The majority of European countries have already prepared strategies for various sectors focusing on the impact of climate change on biodiversity, including water ecosystems.

Significantly, as a result of climate change, the range areas of different species will change, and some of the species specific to a particular region will also be lost. This is widely discussed in the strategies in other countries. Poland is planning to expand its monitoring system for ecosystem changes, with particular emphasis on invasive species (Poland..., 2011).

A broader monitoring network is also necessary in Lithuania, so that timely measures are undertaken to protect important ecosystems in the event of negative changes. In Ireland, it is estimated that 20 percent of local species will be very vulnerable and no less than 52 percent of species are under threat of extinction before 2050 due to climate change. No such forecasts have been made in Lithuania, but they would contribute to the planning of strategies for the adaptation of ecosystems to climate change. In the United Kingdom, a lot of attention is paid to the restoration of degraded habitats, especially the swamps.

To summarize, the ability of lake ecosystems to adapt to changing climatic conditions can reduce potential losses and even benefit from new climate opportunities. *However, considerations of adaptation methods should not ignore the fact that universal technological adaptation measures that would be appropriate for the entire EU territory do not exist, because different measures are appropriate in different local conditions* (Kairu, 2001; Laas, 2012; Angeler, 2015; Cheruvelil, 2008). In order to plan effective measures, it is necessary to carry out a feasibility study for a specific area and then prepare a project for the implementation of socio-economic measures.

It should be emphasized that effective measures that can be proposed for a large area are related to improving the adaptation environment: preparation of legal framework and funding mechanisms for

implementation of adaptation policy, scientific research of sensitivity and vulnerability of various sectors, information, education, risk maps, etc. (Gadkowski, 1980; Heathcote, 2012; Kopf, 2015; Schallenberg, 2013).

Effective measures that can be proposed for a large area are related to the improvement of environment adaptation: preparation of the legal framework and funding mechanisms for the implementation of adaptation policies, scientific research on sensitivity and vulnerability of different sectors, provision of information, education, risk maps, etc. (Karamauz, 2003; Mays, 2001; Polish..., 2013).

Such measures are proposed in national and regional programs and strategies of many countries. Specific measures are usually taken at the local level, e.g. for the coastline, river delta, port, etc.

Conclusions

1. Research on ecosystems and the variety of services they provide is insufficient in Lithuania. One of the reasons is that research must be long-term (for several years), it has to inventorize the ecosystems, assess the quality of their services, establish and support a system for the collection and updating of scientific information about important ecosystem functions.
2. One (rather than 10–12 segmented institutions) institution is required to be responsible at the national level for the regular collection and analysis of ecosystem service data, the development of specialized information systems, and the usage of data for the preparation and coordination of business plans and projects at the national and international levels.
3. In order to preserve the rare fauna of the protected areas, the following socio-economic measures must be applied: promotion of alternative businesses (related to lake ecosystem services) (by reducing the seasonality of the conducted activities); preparation of special free seminars with examples of good practices (not only in Lithuania but also in foreign countries); specialized (according to education, age, performed activities, etc.) distribution of practical information (according to the specifics of actual locations or farms), etc.
4. Currently, there are no common methods that would help to make a qualitative assessment of the impact of changing lake ecosystems on natural resources or individual industries. Therefore, the planning, organization and implementation of adaptation measures for lake ecosystems and the services they provide, including preventive adaptation, are based on nature protection policy while taking into account the specifics of the farm and the local area.

References

- Angeler, D.G., Allen, C., Barichiev, T., Eason, A.S., Garmestani, N.A., Graham, D., Granholm, L., & Nystrom, T. (2015). *Management applications of discontinuity theory*. *Journal of Applied Ecology*. 11, 1365–2664.
- Scottish Environment Protection Agency (SEPA). (2008). *An introduction to the significant water management issues in the Scotland river basin district*. Retrieved January 22, 2020, from <https://www.sepa.org.uk/media/38319/an-introduction-to-the-significant-water-management-issues-in-the-scotland-river-basin-district.pdf>.
- Beklioglu, M., Meerhoff, M., Davidson, T.A., Kemal, A.G., Havens, K., & Moss, B. (2016). *Preface: Shallow lakes in a fast-changing world*. *Hydrobiologia*. Vol. 778.
- Brink, P., Russi, D., Farmer, A., Badura, T., Coates, D., Förster, ... Davidson, N. (2013). *The Economics of Ecosystems and Biodiversity for Water and Wetlands. Executive Summary. IEEP & Ramsar Secretariat*.
- Cáceres, D.M., Tapella, E., Quétier, F., & Díaz, S. (2015). *The social value of biodiversity and ecosystem services from the perspectives of different social actors*. *Ecol. Soc.*
- Cumming, G.S., Hoffman, E., Buerkert, A., & Schlecht, E. (2014). Implications of agricultural transitions and urbanization for ecosystem services. *Nature*. 515(7525), 50–7. DOI: 10.1038/nature13945.
- Cheruvilil, K.S., & Soranno, P.A. (2008). Relationships between lake macrophyte cover and lake and landscape features. *Aquatic Botany*. 88(3), 219–227. DOI: 10.1016/j.aquabot.
- Daubarienė, J. (2012). *Functional Division of Lithuanian Lakes. Doctoral Thesis Physical Sciences, Physical Geography (06P)*, Vilnius.
- The Danish Government. Danish strategy for adaptation to a changing climate. (2008). Retrieved January 22, 2020, from https://www.klimatilpasning.dk/media/5322/klimatilpasningsstrategi_uk_web.pdf.
- Danish Ministry of the environment. Cleaner water in Denmark: Danish water management from the 1970s until today. (2012). Retrieved January 10, 2020, from https://eng.ecoinnovation.dk/media/mst/8051455/Vand_baggrundsartikel_4.pdf.
- De Groot, R.S. (1992). *Functions of nature: evaluation of nature in environmental planning, management and decision-making*. Groningen: VNBV.
- De Groot, R.S., Boumans, R., & Wilson, M. (2002). A typology for the description, classification and valuation of ecosystem functions. *Ecological Economics* 41(3), DOI: 10.1016/S0921-8009(02)00089-7.
- Dirnböck, T., Djukic, I., Kitzler, B., Kobler, J., Mol-Dijkstra, J.P., & Posch, M. (2017). Climate and air pollution impact on habitat suitability of Austrian forest ecosystems. *PLoS ONE*. 12(9), e0184194. DOI: 10.1371/journal.pone.0184194.
- Delgado, L., & Marín, V.H. (2015). Ecosystem services: where on earth? *Ecosystem Services*. 14(3).
- Denmark Environmental Protection Department. Review of the International Water Resources Management Policies and Actions and the Latest Practice in their Environmental Evaluation and Strategic Environmental Assessment Final Report. (2007). Retrieved January 25, 2020, from https://www.epd.gov.hk/epd/SEA/eng/file/water_index/denmark.pdf.
- Downing, J., & Heathcote, A. (2012). Impacts of Eutrophication on Carbon Burial in Freshwater Lakes in an Intensively Agricultural Landscape. *Ecosystems*. 15(1), DOI: 10.1007/s10021-011-9488-9.
- Du Bray, M.V., Stotts, R., Beresford, M., Wutich, A., & Brewis, A. (2019). Does ecosystem services valuation reflect local cultural valuations? Comparative analysis of resident perspectives in four major urban river ecosystems. *Econ. Anthropol.* 6(1).
- Environmental Performance Index. (2018). Yale University. Retrieved February 10, 2020, from <https://epi.envirocenter.yale.edu/downloads/epi2018policymakerssummaryv01.pdf>.
- Gadkowski, M. (1980). Performance of power plant cooling lakes in Poland. *Journal of Energy division*. 106(1).
- Global metrics for the environment: Ranking country performance on high-priority environmental issues. (2018). Retrieved February 10, 2020, from <https://epi.envirocenter.yale.edu/downloads/epi2018policymakerssummaryv01.pdf>.
- Hamilton, D.P., McBride, C.G., Özkundakci, D., Schallenberg, M., Verburg, P., de Winton, ... Ye, W. (2013). Effects of climate change on New Zealand Lakes. In: Goldman C.R., Kumagai M., Robarts R.D. eds *Climate change and inland waters: impacts and mitigation for ecosystems and societies*. John Wiley & Sons, Ltd.
- Heathcote, I.W. (2012). *Integrated watershed management: principles and practice*. New Jersey: John Wiley and Sons.
- Holopainen, I.J., Holopainen, A.L., Hämäläinen, H., Rahkola-Sorsa, M., & Tkatcheva, V. (2003). Effects of mining industry waste waters on a shallow lake ecosystem in Karelia, north-west Russia. *Hydrobiologia* 15.

- Hung, M.C., & Wu, Y.H. (2005). Mapping and visualizing the Great Salt Lake landscape dynamics using multitemporal satellite images, 1972–1996. *International Journal of Remote Sensing*. 26(9).
- Kairu, J.K. (2001). Wetlands use and impact on Lake Victoria, Kenya region. *Lake and reservoirs: research and management*. 6(2).
- Karamouz, M., Szidarovsky, F., & Zahraie, B. (2003). *Water Recourses Systems Analysis. USA: Lewis Publishers*.
- Ke, Z., Xiangdong, Y., Giri, K., Qi Lin, & Ji Shen. (2018). Freshwater lake ecosystem shift caused by social-economic transitions in Yangtze River Basin over the past century. DOI: 10.1038/s41598-018-35482-5. 8: 17146.
- Kopf, R.K., Finlayson, C.M., Humphries, P., Sims, N.C., & Hladyz, S. (2015). Anthropocene Baselines: Assessing Change and Managing Biodiversity in Human-Dominated Aquatic Ecosystems. *BioScience*. Vol. 65, Issue 8. DOI: 10.1093/biosci/biv092.
- Laas, A. (2012). Productivity and nutrient retention of lakes on seasonal, interannual and morphometric scales. (PhD thesis). *Estonian University of Life Sciences*. Retrieved February 10, 2020, from https://limnology.org/wp-content/uploads/2015/06/ALaas2012_PhDThesisFin.pdf.
- Lake Classification and Lakeshore Management Guidebook: Kamloops Forest Region. Forest Practices Code of British Columbia Act. Operational Planning Regulation. (1996). Retrieved February 10, 2020, from <https://www.for.gov.bc.ca/ftp/hfp/external/!publish/FPC%20archive/old%20web%20site%20contents/fpc/fpcguide/kamlake/Kam-toc.htm>.
- Lake Classification and Lakeshore Management Guidebook: Prince George Forest Region. Forest Practices Code of British Columbia Act. Operational Planning Regulation. (1997). Retrieved December 15, 2019, from <https://www.for.gov.bc.ca/ftp/hfp/external/!publish/FPC%20archive/old%20web%20site%20contents/fpc/fpcguide/Guidetoc.htm>.
- Mays, L.W. (2001). *Water Resources Engineering. New Yourk: John Wiley & Sons Ins.*
- Millennium Ecosystem Assessment. Ecosystems and Human Well-Being: Synthesis; Millennium Ecosystem Assessment. (2005). Washington, DC, USA.
- Nakano, T., Tayasu, I., Yamada, Y., Hosono, T., & Igeta, A. (2008). Effect of agriculture on water quality of Lake Biwa tributaries. *Japan Science of the Total Environment*. 389(1).
- Poland information on resource efficiency policies, instruments, objectives, targets and indicators, institutional setup and information needs. (2011). *European Environment Agency*.
- Polish National Strategy for Adaptation to Climate Change (NAS 2020) with the perspective by 2030 Warsaw. (2013). *Ministry of Environment of Poland*.
- Polhill, J.G., Filatova, T., Schlüter, M., & Voinov, A. (2016). Modelling systemic change in coupled socio-environmental systems. *Environmental Modelling and Software*. 75(3), DOI: 10.1016/j.envsoft.2015.10.017.
- Reynaud, A., & Lanzanova, D.A. (2017). Global Meta-Analysis of the Value of Ecosystem Services Provided by Lakes. *Ecological Economics*. 137. DOI: 10.1016/j.ecolecon.2017.03.001.
- Schallenberg, M., de Winton, P., Verburg, D.J., Kelly, K.D., Hamill, & Hamilton, D.P. (2013). Ecosystem services of lakes. In Dymound, J. R. (ed.), *Ecosystem services in New Zealand – conditions and trends. Manaaki Wheneua Press*. Retrieved January 12, 2020, from <https://www.cabdirect.org/?target=%2fcabdirect%2fsearch%2f%3fq%3ddo%253a%2522Ecosystem%2bservices%2bin%2bNew%2bZealand%253a%2bconditions%2band%2btrends%2522>.
- Scholes, R.J. (2016). Climate change and ecosystem services. *Wiley online library*. DOI: 10.1002/wcc.404.
- Scholte, S.S.K., van Teeffelen, A.J.A., & Verburg, P.H. (2015). Integrating socio-cultural perspectives into ecosystem service valuation: A review of concepts and methods. *Ecol. Econ*. 114. Retrieved January 22, 2020, from <https://research.vu.nl/en/publications/integrating-socio-cultural-perspectives-into-ecosystem-service-va>.
- Scottish climate change adaptation programme 2019–2024: strategic environmental assessment. (2018). Retrieved January 22, 2020, from <https://www.gov.scot/publications/climate-ready-scotland-scotlands-climate-change-adaptation-programme-2019-2024-strategic-environmental-assessment/>.
- Smith, H.F., & Sullivan, C.A. (2014). Ecosystem services within agricultural landscapes—Farmers’ perceptions. *Ecol. Econ*. 98. DOI: 10.1016/j.ecolecon.2013.12.008.

TESTING AN OPERATION OF PROTOTYPE FOR AUTOMATED ASSESSMENT: CASE OF VISITOR PROFILE OF GAUJA NATIONAL PARK

***Iluta Berzina, Edgars Balodis**

Vidzeme University of Applied Sciences, Latvia

*Corresponding author's email: iluta.berzina@va.lv

Abstract

This study is based on the authors' research started in 2017 that resulted in the development of theoretical strategic and tactical models for the construction of a prototype for automated assessment of tourism economic impact in specific regions, including regions of national parks (NP), as well as for other studies. The aim of the research was testing the performance of the prototype in a research e-environment using the travellers' survey data obtained in a study in 2019 on the national parks' target groups (visitor behaviour) during the Gauja National Park (GNP) Travellers' Days. The prototype was based on the open-source platform Drupal, MySQL used as a database management system (DMS). Drupal united with the Jupyter Notebook platform. The methodological substantiation of the test study is based on aspects of consumer behaviour. A quantitative study with details of qualitative research has been performed. Simple data sampling was used in the data acquisition, but in the analysis – induction, deduction approach, synthesis, data sorting and segmentation, determination of mean values and their expression in proportion; a comparative analysis was performed and conclusions characterizing the sample were made. After completing the prototype performance testing, the authors' main findings indicate that the prototype's performance efficiency in terms of time consumption is 23.3 times higher than equivalent work in MS Excel. The prototype has yielded quantitative results from the calculations, and that allows the formulation of the GNP's Travellers' Days visitor profile, which is characterized by a sample of the surveys.

Key words: prototype, automatized assessment, visitor profile.

Introduction

Technologies are constantly evolving in the world, developing a digital era. The market intelligence company 'International Data Corporation' (IDC) believes that digitized information has the potential for a variety of applications that facilitate work in the e-environment. The IDC has named three primary locations where digitalization is happening and where digital content is created: (1) the core (traditional and cloud data centres), (2) the edge (enterprise-hardened infrastructure like cell towers and branch offices), and (3) the endpoints (PCs, smart phones, and IoT devices). The summation of all this data, whether created, captured, or replicated, is called the Global Datasphere, and it is experiencing a tremendous growth. The IDC predicts that the size of the Global Datasphere will grow from 33 Zettabytes (ZB) in 2018 to 175 ZB by 2025. According to the IDC's 'Data Age 2025' white paper, it means, if a person attempts to download 175 zettabytes at the average current internet connection speed, it would take 1.8 billion years to download. The real-time data represents 15% of the Global Datasphere and nearly 30% by 2025 (BWMC Ltd, 2020; Reinsel, Gantz, & Rydning, 2018).

Much of today's economy relies on data, and this reliance will only increase in the future. Data is helping reach new markets, streamline operations, helps better recognize, serve and attract customers, and analyse several processes (Reinsel, Gantz, & Rydning, 2018).

For example, in Latvia the territory of national parks (NP) is divided into functional zones according to conservation and utilization purposes. In some of these zones, natural resources are completely excluded

from economic and other activities, or only economic activities that do not significantly change the structure of the historically formed landscape, including natural and cultural values, are allowed (Saeima of the Republic of Latvia, (the Parliament), 1993). It is therefore important to develop a sustainable tourism business and to elaborate a sustainable tourism product strategy in the NP territories. It is justified by the reasoning made in the data-based evaluation of the situation. This is why the Nature Conservation Agency of Latvia (LNCA) in collaboration with the Association 'Cesis District Rural Partnership' (CDRP) and the Northern Kurzeme Business Association (NKBA) conducted a study on national parks' target groups (visitor behaviour) in two NPs in the period 2018–2019 which was carried out by the Institute of Social, Economic and Humanities Research of Vidzeme University of Applied Sciences (ViA HESPI). The aim of the study was to obtain information to support the development of strategic documents for sustainable management and development of territories by exploring the behaviour – unknown facets of the Slitere NP (SNP) and Gauja NP (GNP) target groups (Association CDRP, 2019). According to the study objectives defined by the LNCA, the target group for the particular study was NP visitors. The required primary data was collected during 2018–2019 Traveller Days, incl. in the GNP – 15–16 September 2018 and 14–15 September 2009. These events provide easier access to the target group, and hence the data, and the NP Traveller Days focus on both the most typical NP tourism offer and the most characteristic demand.

It is noteworthy that until 2018 there was only

one NP Travellers' Days evaluation carried out - as a feedback from the target group of the first SNP Travellers' Day event in 2010. It was carried out by the Professional Rural Tourism Association 'Rural Traveller' (PRTA RT, 2010). The time-consuming and manual work-intensive MS Excel environment was used, in comparison with the performance of any database software.

However, the digital era reflects in science. The usual triad 'researcher-research tools-object of research' is changed and turns into a cyber-physical system – a new triad 'engineer-design tools-prototype/product' interpreting scientific results by new research techniques or/and methodologies (Gero, Tsybulsky, & Levin, 2019).

This study is based on the authors' research work started in 2017 that resulted in the development of theoretical strategic and tactical models for the construction of the prototype. It is based on a combination of open source platform capabilities in order to automate the process of assessing the economic impact of tourism in specific regions, including NP regions, as well as to perform other studies using the data stored in the 'Data Bank' section of the prototype. The prototype consists of two interconnected digital applications – 'Data Bank' and 'Data Analysis' – as a unified solution for research in the e-environment. At the present stage, it integrates the methodology developed in 2012 in Latvia University of Agriculture (now Latvia University of Life Sciences and Technologies) for assessing the economic significance and the impact of tourism in specific regional areas (Berzina, 2012), without the possibility of statistical analysis (statistical verification of results), as well as the theoretical possibility of using mobile positioning data (MPD) so that results can be expressed spatially (Berzina & Lauberte, 2018; Berzina & Lauberte, 2019).

Mobile data is the internet content delivered to mobile devices such as smartphones and tablets over a wireless cellular connection (TechTarget Ltd, 2020). In the world, MPD-based technologies are evolving just like MPD consumption. This is evidenced by the global study carried out by Swedish company Tefficient AB Ltd in 2019 which concludes that Europe is a world leader in mobile data consumption and growth. In 2018 in Europe, JSC Latvia Mobile Telephone (LMT) ranked 5th in the world by mobile data usage (GB) per month per unique user (SIM) (19.2 GB / SIM), Tele2 – 8th (10.3 GB / SIM), but Bite LV – 13th (7.6 GB / SIM), while Finland was the world leader (the company DNA – 23.5 GB / SIM), but Italy (103%) showed the fastest growth (Tefficient AB Ltd, 2019). However, there is a prolonged stagnation in the practical availability of anonymised MPD in Latvia for research purposes. Mobile network operators (MNOs)

do not provide data on the basis of Regulation (EU) 2016/679 on the protection of natural persons with regard to the processing of personal data and on the free movement of such data which entered into force on 25 May 2018 (EP & EC, 2016). Latvia is in the process of searching for a fundamental solution in the potential use of MPD. Namely, on 1 January 2019 the amendments to the Electronic Communications Law (2004, with amendments made until 16 January 2020) came into force in the Republic of Latvia (LR), which stipulate that the Central Statistical Bureau of Latvia (CSB) has the right to use the data at the disposal of MNOs for the provision of statistics (LR Saeima (the Parliament), 2004). However, there are no regulations of LR Cabinet of Ministers on how to ensure it. There are on-going discussions on the development of the regulations and the result is not expected soon. 'It is possible that MNOs are seeing not only an innovative approach here, but also a new business niche alongside the existing services. For example, LMT is based on the model that the company operates with its own data and can, by attracting researchers, prepare solutions for government or commercial organizations. Consequently, the question of who will do the research and how it will be done remains open in Latvia' (Jurkāns, 2019). Nevertheless, the ability of the prototype to work with MPD has been tested using synthesized MPD. The results obtained do not allow affirming, but allow suggesting that at least theoretically the prototype can recognize MPD. The MPD synthesis used a structure (anonymised CDR data including call and internet usage time, GPS coordinates, mobile device (not number) ID, SIM residency) that was included in the 2017 Liberia example – report 'Call Detail Record (CDR) Analysis: Republic of Liberia. Final Report. Republic of Liberia 2017' (ITU, 2017).

The aim of the research: testing the performance of the prototype in a research e-environment using the travellers' survey data obtained in the study conducted by ViA HESPI in 2019 on the national parks' target groups (visitor behaviour) during the Gauja National Park (GNP) Travellers' Days in order to determine the GNP visitor profile. Tasks of the research are as follows: (1) Test the technical operation of the prototype; (2) Describe the operation of the prototype; (3) Present the results of the test study regarding the visitor profile of the GNP Travellers' Days; (4) Draw conclusions.

Materials and Methods

The methodological substantiation of the test study is based on the aspects of consumer behaviour (action), which are evaluated in market research in social, economic, marketing, etc. areas, and are related to external and internal factors of an

individual's purchasing or consumption decision: (1) Economic (income level, solvency); (2) Social (belonging to a particular social class, status in society, etc.); (3) Cultures (cultural level, educational level, nationality, religion); (4) Personal (age, life cycle stage, profession, lifestyle, character, etc.); (5) Psychological (motivation, perception, attitude, habits) (Association CDRP, 2019). There is no better way to objectively understand the current situation than to organize a survey – collect information from respondents in the locations (e.g., lodging properties, restaurants, attractions, retail shops, and outdoor recreation spots, etc.) they have visited while in a destination (University of Minnesota Extension, 2020). The methodology applied is a combination of a number of scientific techniques which was developed and scientifically approbated in 2011 when formulating the profile of the Kemer NP (KNP) visitor profile. It is based on a combination of research techniques developed and tested in Australia, the USA and Finland, which is based on surveys (or interviews) as the data acquisition method. The questionnaires are quite complex and include: (1) Filter questions; (2) Structured answer questions (closed questions); (3) Multiple choice questions; (4) Dichotomous choice questions; (5) Unstructured answer questions (open questions); (6) Free-answer questions; (7) Response scale (Berzina & Grizane, 2011). For the purpose of investigating the target group, the questions in the survey are organized so that the data can be segmented into 4 criteria groups. They consist of several sub-criteria: (1) Demography – gender, age, place of residence, education, occupation, work status, composition of the traveller group, income, travel expenses, willingness to pay; (2) Activities – frequency of travel, destination of the trip, length of stay in the territory of the NP, place of stay, mode of travel, attendance of events; (3) Acquisition of

information; (4) Attitudes - the motive of the trip, travel decision factors, the overall rating of the NP Travellers' Day and the assessment of the likelihood of recommending to others, alternative choices (Berzina & Grizane, 2011). In this approach, the final score is the result of each assessment with the highest frequency ('majority wins') in the analysis after the data collection, thus yielding a higher arithmetic mean value, which is normalized in proportion to the sample set. The total sample of n = 268 consists of the GNP Travellers' Day direct target group – NP visitors (Association CDRP, 2019). In order to determine the GNP visitor profile, quantitative research with details of qualitative research was performed in the prototype testing. For acquisition of primary data, simple random sampling was used, where the principle of equality is respected. The results, on the other hand, are the result of a partial statistical observation of a part of the general set – a sample, with the purpose of obtaining a general idea. Induction, deduction approach, synthesis, data sorting and segmentation, determination and expression in proportion, qualitative information quantification was used, comparative analysis was carried out, conclusions regarding the sample were made (Association CDRP, 2019).

The research used a part of the data set that could be obtained and processed even for the analysis of tourism EI – on the principles of this analysis the prototype design and technical development were based. For the sake of controlling the accuracy of the results, the study was carried out both in MS Excel and by using the prototype capabilities for automated acquisition of results, which is not related to the inclusion of MPD (Figure 1).

The model is based on the open source platform Drupal that ensures that there is no need to buy/subscribe to licenses. MySQL is used as a database management system (DMS) for 'Data bank' of

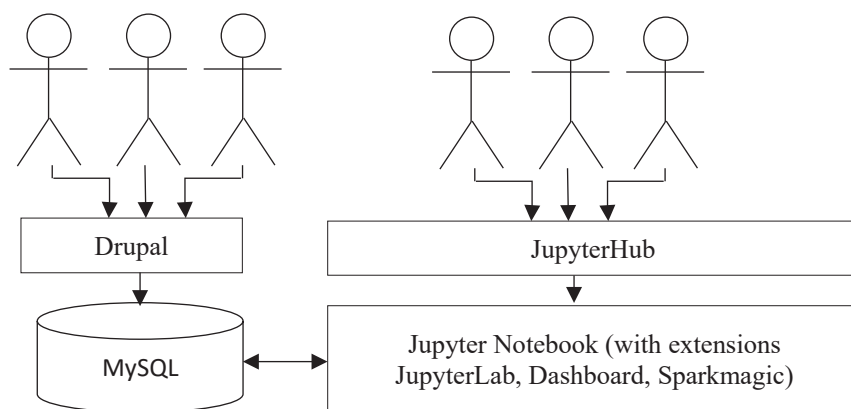


Figure 1. Tested part of the prototype – fragment of the tactical model for the construction of the prototype for automatized assessment of appropriate tourism issues (Created by the authors, according to Berzina & Lauberte, 2019).

traditional data. Using the 'Data Bank' content management system (CMS), Drupal authorized users are able to create new multi-language survey forms, sort the data submitted there, and create new data views. The 'Data analysis' interactive interface allows an easy and fast data analysis. Drupal united with the Jupyter Notebook platform and extensions, and the code developed in the Python languages to get the power for actions by data, because Drupal has the ability to collect information, but Jupyter Notebook – to process and analyse traditional data (Berzina & Lauberte, 2019). In accordance with the prototype Software Design Description (SDD), the prototype includes the following users and their roles:

(1) System Administrator – as an authorized user with full system administration rights, he/she creates and/or corrects any content, data fields, views; he/she creates new domain entries and their paths, administers users and their rights, translates the application interface, administers blocks and modules, site menus, default configuration and changes its appearance. He/she views, deletes audit log entries;

(2) Content Administrator – as an authorized user who has the right to edit existing, create and publish new questionnaires, as well as translate their content, he/she views, edits all submissions of all questionnaires, views revisions of value changes entered by external data sources and restores/ deletes records. He/she administers existing content types, input fields, data views, administers the main menu bar, as well as the tool menu block;

(3) Public user (respondents) – fills in the questionnaire;

(4) Analyst – as an authorized user who has the right to edit existing, create and publish new questionnaires, as well as translate their content. He/she views, edits all submissions of all questionnaires, enters data from external data sources, views their value change revisions, restores/ deletes entries.

Results and Discussion

The testing sequence according to the prototype user roles:

(1) System administrator, while performing all the functions of the role, played a continuous observer and consultant role in the testing as he is also the technical developer of the prototype. The main view of the prototype shows its structural units – menus, tabs, tools, question groups in the questionnaire. When testing the performance of the prototype, no negative features were observed in the performance of the system administrator and at the same time the technical developer of the prototype;

(2) Content Administrator – In the 'Data bank' section of the prototype, 1 questionnaire in Latvian was created and published, consisting of 26 questions,

one of which was an unstructured or open question. The questionnaire consisted of 7 open-ended question answers and 5 answer scales. This is part of the administration of content (response) types, input fields, data views. When administering the main menu bar, the tool menu block was organized. According to the methodology used, the study did not require input of external (secondary) data or value change revision. Therefore, the 'External Data' block in the 'Database' part of the prototype developed by the system administrator was not used in the test study, although its performance was verified by the analyst using synthesized data – entering and then deleting them. In this way, both the particular block and the other entry sections were technically tested. The possibility of restoring or deleting entries was used to correct some inadvertent errors that occurred during the data entry. No negative features were observed in the performance of the prototype;

(3) Public User (Respondents) – during the testing of the prototype, the public user function was performed by the analyst by manually transferring the data from the questionnaires in printed format into electronically prepared questionnaires in the 'Data bank' section of the prototype. They were available on 4 mobile technical devices – 2 tablets and 2 mobile smartphones – and 1 computer via a single Internet Protocol (IP) address created using WiFi over a wireless local area network. The prototype development phase does not provide for the creation and subscription of a domain that would allow data to be entered online, i.e. through one of the internet browsers. No negative features were observed in the performance of the prototype;

(4) Analyst – also given the role of the content administrator, but during the test study the analyst performed the data analysis of all the submissions in the questionnaire according to the methodology, i.e. segmentation of the data, summation, expression in proportion and visualization in bar graphs. The answers of the open-ended questions were segmented, the prototype divided them and created a list of answer variants also according to the segments. All the results can be exported in csv format and saved on a Drupal server for opening the file. Concurrently with the work in the prototype environment, the test study data entry and the calculations of the results were performed also in the MS Excel environment. The difference observed when comparing the results in the two environments used was in the final result, which showed up at the seventh digit after the decimal point – a change of one digit sometimes in the direction of value growth and sometimes in the direction of decline. Therefore, it can be generally considered that no negative features were observed in the performance of the prototype.

According to the methodology, in the prototype component 'Data Analysis' the division of respondents into three segments was performed: (1) NP inhabitants, (2) one-day travellers and (3) tourists. It is the basis of the structure for characteristics and calculations included in the assessments. At this moment, the prototype is able to perform the functions of summation and comparison (difference determination), in specific cases – division, multiplication and expression of results in percentage (%). The determined profile of the direct target group of the GNP Travellers' Days: A woman living in Latvia – a one-day traveller aged 16–45 with a university degree having a job in trade or finance sector. The monthly salary is up to 500–900 EUR. She spends the weekend in the GNP Travellers' Days travelling with 3–4 family members, friends, relatives or acquaintances aged 18–65. She repeatedly visits the GNP Travellers' Days though it is not the destination of her trip. She covers a distance of up to 100 km, travelling by a private car and spending up to 1.5 hours during the trip. When attending the event, her expenses of up to € 20 are mostly made up of transportation-related and catering services, and the woman would not like to see any further increase in costs. While attending the GNP Travellers' Days, she is confident that the GNP area is a clean, natural and safe environment, as well as expects valuable event programme content, and the area is easily accessible having the necessary infrastructure. It is of little importance to her that the GNP area is a Natura 2000 site. She plans to spend between three hours and one day on the GNP territory. The woman gets information about the destination and event from news on the web and from communication with friends, relatives, acquaintances or colleagues. As an alternative to visiting the GNP's Travellers' Days, the traveller would choose to stay home or visit relatives, friends, acquaintances or colleagues. The attended activities of the event are rated with 4–5 points, but she would wish for a variety of activities, better value for money and thinks that the provision and availability of information is a major issue to be improved by the event organizers.

From the technical point of view, these are not complicated procedures and at this point the right choice of the programming language was the database management system (DMS) MySQL for traditional data. It remains unknown whether the Diederich T. (2018) finding that MySQL is not suitable for large scale high-quality data analysis (Diederich, 2018) can be supported because the 'Data bank' part of the prototype does not contain a large array of data that can be generated over time, in larger and more frequent surveys, and also if the prototype had been developed so far that statistical verification of the obtained research results would be possible. During

the test procedure, the authors obtained assurance that the prototype built on the Drupal platform worked fast, the CMS was easy to understand for users regardless of their role (except for the public user who did not need to understand it). The previous theoretic assumption was confirmed, namely, that Drupal is a lightweight platform made for fast performance and it has features for managing content types, which is useful for creating data views, and it has a good user permission management. The Drupal use is free of charge and does not require special permits and licenses (Berzina & Lauberte, 2019). The survey data of research site visitors is stored in the MySQL database, just like the data analysis results in the data analysis section. Since Jupyter Notebook is an open-source web application that allows creating and sharing documents that contain live code, equations, visualizations and narrative text, it was used as a prototype technical development tool by the system administrator when creating the visualization code for the analysis of the results in Python programming language. In the test study, no negative features were observed in the visualization of the results, confirming that the use of the Jupyter Notebook in the prototype development was useful, allowing to obtain results that are also expressed in bar graphs.

If the functions of the prototype are evaluated in comparison to MS Excel, the authors have arrived at several conclusions and also agree with Natter, E. (2019) – MS Excel spreadsheets are frequently used tool for collecting and organizing data, which is among the simplest of its uses. Information can be placed in columns and rows, sorted by information type, analysed and put into charts or tables for viewing and interpretation. However, the downside is that only the information that the user chooses for analysis is included in these presentations, and therefore, other pertinent information that may influence decision making might be excluded. The difficult part for users is that the calculations must be entered into the spreadsheet as formulas. This requires learning the correct syntax for each type of calculation. However, many classes are available to learn the skills necessary to use these formulas. If the syntax is incorrect, the programme will not return the correct information when the calculations are run. Additionally, if users input wrong data, even in only one cell of the spreadsheet, all related calculations and cells will be affected and have incorrect data. In today's collaborative work environment, multiple users often need access to the same documents. If using MS Excel, the spreadsheets can be shared, but only one user can change data at a time. Fundamental deficiency – there is no file history. Another spreadsheet disadvantage is the lack of security for files. Some data collection software therefore may be a more suitable option

Table 1

**Processing time of questionnaire and data in MS Excel and prototype environments
(Created by the authors)**

Sequence of actions performed	Indicators/ criteria groups				MS Excel (spent time h:m:s)	Prototype (spent time h:m:s)
‘Data bank’						
Preparation of questionnaire					01:06:00	00:49:00
Data entry					00:05:00*	00:01:00**
‘Data analysis’						
	Demography	Activities	Information sources	Attitude		
Selection of data	00:03:30	00:03:30	00:02:00	00:03:30	00:12:30	00:03:00
Summing of data	00:01:00	00:01:00	00:01:00	00:01:00	00:04:00	00:00:06
Results expression in proportions (%)	00:04:30	00:04:30	00:01:00	00:04:30	00:14:30	00:00:05
Selection and preparation (sorting) of results for visualisation	00:06:00	00:06:00	00:03:00	00:06:00	00:21:00	00:00:04
Visualization of results (graphic presentation)	00:08:00	00:08:00	00:05:30	00:08:00	00:29:30	00:00:12
Total:					01:20:30	00:03:27

* Data entry on one device (1 questionnaire)

** Data entry from five devices simultaneously (5 questionnaires)

(Natter, 2019). The mentioned shortcomings of MS Excel are not observed in the prototype environment and work on it requires significantly less time. The authors present an example of processing the data of five questionnaires (Table 1).

Despite the fact that the time consumed depends on both the size and complexity of the questionnaire and human factors such as the speed of work, it has been concluded in the result summary that working in the prototype environment is more efficient in terms of time spent both for questionnaire design, data entry and analysis processes. In total, the work in the prototype environment with the questionnaire and the data starting from input to result using 5 questionnaires from 3 different respondent segments as well as 5 devices consumed 23.3 times less time than the same workload in MS Excel environment. Therefore, the use of the prototype in data input, selection, filtering, transformation in order to perform data preparation for analysis and also the analysis and visualization of results can be considered more efficient than the use of MS Excel. One of the reasons – MS Excel is not suitable for multi-user mode, unlike the prototype capabilities – data entry can occur simultaneously from an unlimited number of devices and data consolidation is done immediately because it is automatic. In addition, MS Excel is only integrated with MS infrastructure, which are often paid products,

besides that, the user should have a good knowledge of MS Excel. There are no such restrictions in the use of the prototype, although the results can be opened and saved in csv format, as provided also by MS Excel.

Conclusions

1. The performance of the prototype, corresponding to its stage of technical development, has been tested and demonstrates that:
 - 1.1. Drupal is fast-performance and it has features for managing content types, which is useful for creating data views, and it has a good user permission management;
 - 1.2. From the technical point of view, it was the right choice of the programming language selection where the database management system (DMS) MySQL for traditional data was used. It remains unknown whether Diederich T. (2018) finding that MySQL is not suitable for a large scale high-quality data analysis can be supported;
 - 1.3. The use of Jupyter Hub and Jupyter Notebook with extensions in the development of the prototype has been useful;
 - 1.4. Users’ roles did not cause any problems in the prototype testing. This allows assuming that they are organized in an appropriate hierarchy and proportions;

- 1.5. Collecting and analysing the data necessary for research requires 23.3 times less time in the prototype environment compared to the same workload in the MS Excel environment;
2. By using the prototype, the authors have been able to determine the profile of GNP Travellers' Days visitors, which is characterized by a sample of the survey. The methodology used to determine the visitor profile is consistent with the current technical capabilities of the prototype to perform automated simple calculations;
3. The technical development of the prototype should be continued, so that the statistical verification of the obtained research results can also be performed.

Acknowledgements

The article is prepared in the frame of the PostDoc research project 'Integrated Design of Techno-Social Systems: Next Generation of Tourism Monitoring in Latvia' (10.08.2017. Decision No. 9.-14.1/5018 of The State Education Development Agency of Latvia; Project No. 1.1.1.2/VIAA/1/16/110) and supported by the European Regional Development Fund (ERDF).

The authors of the article are grateful to the Nature Conservation Agency of Latvia (LNCA) and the Institute of Social, Economic and Humanities Research of Vidzeme University of Applied Sciences (ViA HESPI) for the permission to use the primary data obtained during the study on national parks' target groups (visitor behaviour).

References

- Association 'Cesis District Rural Partnership (CDRP)' (2019). *Nacionālo parku mērķgrupu (apmeklētāju uzvedības) izpēte. (Study on National Parks' Target Groups (Visitor Behaviour))*. Retrieved January 23, 2020, from http://www.ziemeļkurzeme.lv/userfiles/files/328/CRLP_PeTiJUMA_ZInOJUMS_Final.pdf. (in Latvian).
- Berzina, I. (2012). *Assessment of Tourism Economic Significance in the Regions of National Parks of Latvia*. Unpublished doctoral dissertation (Full text), Latvia University of Agriculture, Jelgava, Latvia.
- Berzina, I., & Grizane, T. (2011). Ķemeru Nacionālā parka apmeklētāja profils. (Visitor Profile of Kemeru National Park). RPIVA VI Conference of New Scientists, 5 May 2010 (pp. 186–192). Riga, Latvia, RPIVA: ISBN 978-9934-8215-7-8. (in Latvian).
- Berzina, I., & Lauberte, I. (2018). The Model of Automation and Extension of Tourism Economic Impact Assessment in Specific Regions. In Annual 24th ISC Research for Rural Development 2018 Vol. 2, 16–18 May 2018, (pp. 195–202). Jelgava, Latvia: Latvia University of Life Sciences and Technologies. DOI: 0.22616/rrd.24.2018.072.
- Berzina, I., & Lauberte, I. (2019). Tactical Model for Constructing a Prototype of Automatized Assessment of Tourism Economic Impact. In Annual 25th ISC Research for Rural Development 2019 Vol. 2, 15–17 May 2019, (pp. 232–239). Jelgava, Latvia: Latvia University of Life Sciences and Technologies. DOI: 10.22616/rrd.25.2019.074.
- BWMC Ltd (n.d.). *How Much Data Is There In The World?* Retrieved January 20, 2020, from <https://www.bernardmarr.com/default.asp?contentID=1846>.
- Diederich, T. (2018, January 5). 5 Limitations of MySQL with Big Data, Friday. GridGain. Retrieved March 2, 2020, from <https://www.gridgain.com/resources/blog/5-limitations-mysql-big-data>.
- EP & EC (2016, April 27). Regulation (EU) 2016/679 of the European Parliament and of the Council of 27 April 2016 on the protection of natural persons with regard to the processing of personal data and on the free movement of such data, and repealing Directive 95/46/EC (General Data Protection Regulation). *Eur-Lex*. Retrieved February 02, 2020, from <https://eur-lex.europa.eu/eli/reg/2016/679/oj>.
- Gero, A., Tsybulsky, D., & Levin, I. (2019). Research and design triads in the digital epoch: implications for science and technology education [Journal Article]. *Global Journal of Engineering Education*. 21(1), 80–83. Retrieved January 26, 2020, from https://www.researchgate.net/publication/331841044_Research_and_design_triads_in_the_digital_epoch_Implications_for_science_and_technology_education.
- International Telecommunication Union (ITU) (2017). Call Detail Record (CDR) Analysis: Republic of Liberia. Final Report. Republic of Liberia: ITU Telecommunication Development Sector. ISBN (electronic version): 978-92-61-20291-0. Retrieved February 20, 2020, from <https://www.itu.int/en/ITU-D/Emergency-Telecommunications/Documents/2017/Reports/LB/D012A0000C93301PDFE.pdf>.
- Jurkāns, I. (2019, March, 3). Mobilo ierīču dati: cik noderīga ir šāda informācija tiem, kas plāno Latvijas attīstību? (*Mobile Data: How useful such information is for those planning Latvia's development?*). *SIA All Media Latvia*. Retrieved February 25, 2020, from <https://skaties.lv/zinas/latvija/mobilo-iericu-dati-cik-noderiga-ir-sada-informacija-tiem-kas-plano-latvijas-attistibu/>. (in Latvian).
- LR Saeima (the Parliament) (1993, March 2). Likums Par īpaši aizsargājamām dabas teritorijām (ar Grozījumiem, kas izdarīti līdz 11.01.2014.) (Law On Specially Protected Nature Territories (1993, with amendments

- made until 11.01.2014.)). *Latvijas Vēstnesis*. Retrieved February 01, 2020, from <https://likumi.lv/ta/en/en/id/59994-on-specially-protected-nature-territories>. (in Latvian).
- LR Saeima (the Parliament) (2004, October, 8). Elektronisko sakaru likums (ar Grozījumiem, kas izdarīti līdz 16.01.2020.) (Electronic Communications Law (2004, with amendments made until 16.01.2020.)). *Latvijas Vēstnesis*. Retrieved January 30, 2020, from <https://likumi.lv/ta/id/96611-elektronisko-sakaru-likums>. (in Latvian).
- Natter, E. (2019, February 25). The Advantages & Disadvantages of Spreadsheets. *Houston Chronicle, Hearst Newspapers, LLC*. Retrieved March 5, 2020, from <https://smallbusiness.chron.com/advantages-disadvantages-spreadsheets-26551.html>.
- PRTA RT (2010, June). *Slīteres Ceļotāju dienas vēstnesis. (Slītere Travellers' Day Bulletin)*. Retrieved January 15, 2020, from https://www.celotajs.lv/cont/conf/conference/100612-CD/avize/avize_slitere_2.pdf. (in Latvian).
- Reinsel, D., Gantz, J., & Rydning, J. (2018, November). *Data Age 2025. The Digitization of the World From Edge to Core*. Retrieved January 20, 2020, from <https://www.seagate.com/files/www-content/our-story/trends/files/idc-seagate-dataage-whitepaper.pdf>.
- TechTarget Ltd (2020). *Mobile data*. Retrieved March 5, 2020, from <https://whatis.techtarget.com/definition/mobile-data>.
- Tefficient AB, Ltd (2019, September, 5). *Mobile data consumption to grow – a majority of operators now rewarded with average revenue per user (ARPU)*. Retrieved February 25, 2020, from <https://tefficient.com/wp-content/uploads/2019/09/tefficient-industry-analysis-3-2019-mobile-data-usage-and-revenue-1H-2019-per-operator-5-Sep.pdf>.
- University of Minnesota Extension (2020). *Visitor profiles*. Retrieved February 27, 2020, from <https://extension.umn.edu/research-communities/visitor-profiles#what-information-is-collected%3F--1522361>.

DEVELOPMENT OF ECOSYSTEM SERVICE OPPORTUNITIES IN THE NEMUNAS DELTA IN THE CONTEXT OF GLOBAL CLIMATE CHANGE

Vytautas Pilipavičius¹, *Jan Žukovskis²

¹Vytautas Magnus University, Lithuania

²Klaipėda University, Lithuania

*Corresponding author's email: jan.zukovskis@vdu.lt

Abstract

The second half of the 20th century brought to light the consequences of human activity, when Humanity was confronted with demiurgical complexes and realized that the planet Earth was not only nature, but a complex system that today could no longer be operated by traditional methods and logic. While until the middle of the 20th century man used natural resources only to meet his needs, the 21st century poses new challenges for mankind to manage the consequences of human activities and to use them rationally and sustainably.

The paper presents a study aimed at assessing the potential of ecosystem services development in the Nemunas Delta and anticipating their development directions. As a result of the research, the possible development directions of the Elderships were presented. It was done in two scenarios.

The research was carried out in six municipality subdivisions (elderships) of the Nemunas Delta area in the framework of the Lithuanian Science Council project *'Interaction of ecosystem services and human activities in the context of climate change'*. Preparation of this paper was supported by funding from European Social Fund (project No 09.3.3-LMT-K-712-01-0178) under the grant agreement with the Research Council of Lithuania (LMTLT).

Key words: climate change, development, ecosystem services, elderships.

Introduction

Rapid economic development in the 20th century has shown that a Man, believing in the absolute power of scientific and technical progress, has become the master of nature, able to transform nature in its own way so that it can meet its ever-increasing needs. There is a widespread belief that increasing material production is the only true measure of society's progress and prosperity. By the end of the 1960's, environmental pollution had reached a level where it was no longer possible to devote no attention to the problem.

Managing the consequences of human activities, through the rational and sustainable use of natural resources while ensuring the repeatability of living conditions for future generations, poses new challenges for the 21st century community.

The European Union has linked the development to a smart, sustainable and inclusive growth (EU 2020 strategy), taking into account the consequences and projections of global change.

The Lithuanian Parliament approved the National Climate Change Management Policy Strategy for 2013–2050 (National Climate Change ..., 2012). This strategy foresees the need to formulate and implement Lithuania's climate change management policy – mitigation and adaptation, defining short-term (by 2020), medium-term (by 2030 and 2040) and long-term (by 2050) goals and objectives.

The Lithuanian Science Council project *'Interaction of Ecosystem Services and Human Activities in the Context of Climate Change'* aimed to highlight the directions of ecosystem services development in the Nemunas Delta in the context of global climate change.

The aim of the study is to evaluate the development possibilities of ecosystem services in the Nemunas Delta and to predict the directions of development.

Objectives:

- To provide methodological provisions for the study of the development of ecosystem services;
- To conduct empirical research on the development of ecosystem services in the Nemunas Delta;
- To summarize the data of empirical research and to envisage directions of development.

For the research, scientific literature and documentary sources have been analyzed, and the content analysis and empirical research methods have been used.

Materials and Methods

The turn of the 20th and 21st centuries, with the acceleration of scientific and technological advances and new socio-economic opportunities and prospects, is characterized by radical changes (Melnikas, 2002). Change can be perceived in two ways: change is one of the common causes of human development and progress; change is an essential result of global development and progress. In other words, change is determined by the existence of human beings in the evolution of human life – natural processes and change initiated by organized human activities that shape the progress of human life – artificial processes (Grigaliūnienė, 2000).

Ecosystem services are opportunities provided by the ecosystem as natural artefacts that become resources in the human development process.

Today, the complexity of the interaction between the worlds of nature and human activity is being

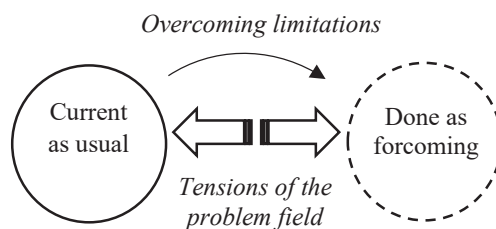


Figure 1. Developments in Overcoming Limitations.

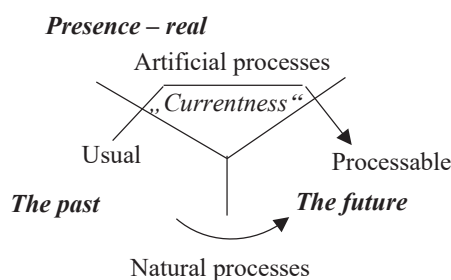


Figure 2. Tensions of the problem field (Щедровицкий, 2019).

actualized in terms of global climate change. The source of change – development, as the initiator of change, manifests itself in overcoming the limitations of traditional thinking, Figure 1.

Problem field tensions are stability interruption situations arising in the process of change that create preconditions for development and require new situation definiteness in the past-future-present interaction, Figure 2.

Today, in the context of global change access (Schwab, 2018), we can associate development with the shift from traditional οίκος ημοιος to smart ways of organizing οίκος λοιος, capturing the tensions of the problematic field in three dimensions of time: being as acting reality in relation to the past (what is past); you are in touch with the present (what is real); you are in touch with the future (what is to come).

Development is based on a complex, systemic nature, providing reproductive, developmental, and investment functions (Мескон *et al.*, 2004).

Reproductive functions associated with problematization of the ‘being’ in the present-past tension, ensuring continuous functioning in the short term, focused on the repetition of lifestyle conditions.

Improvement functions with problematization of the ‘being’ in the tensions of the present and the future, in order to progress in the medium term with a view to improving the quality of life.

Investment functions – with the problematization of the ‘being’ as done in the tension of the future and as usual as in the past, in the long-term perspective of strategic development focused on shaping the future lifestyle.

Integrated development of ecosystem services is directly related to the concept of sustainable

development (A Short History of ..., 2015), as an instrument of sustainable development, responsible social behaviour, ensuring the connection between investment and territorial development, solving problems of care change and shaping future social clutches of cultural lifestyles and other contemporary global issues that reflect a new tradition.

Methodology of Empirical Research

An empirical study has been carried out to analyse the feasibility of developing ecosystem services in the Nemunas delta in the context of global climate change.

- Assessment of potential problems of climate change consequences in the Nemunas delta area;
- Analysis of the status and trends of the Nemunas Delta ecosystem services;
- Analysis of relevance and foresight of climate change management directions in the Nemunas Delta.

The questionnaire was based on the International Climate Change Commission (IPCC) projections on the major consequences of climate change (Контантинов, 2018), research conducted in Lithuania (Climate Change ..., 2017), Common International Systematic Classification of Ecosystem Services (CICES) and the European Commission’s Covenant of Mayors for Climate and Energy (Climate Change and Adaptation ..., 2017) documents.

The study included an assessment of the state of ecosystems and their development trends, as well as a comparative analysis. The evaluation was performed on a scale from 0 to 3. The results of the study are presented in graphs.

Table 1

Hierarchy of potential problems of climate change consequences

No.	Climate change phenomena	Hierarchy (1 – most important, 8 – least important)					
		Farmers	Tourist farmsteads	Communities	Experts	Sum	Average
1	Increasing recurrence of dangerous natural phenomena	3	1	1	1	6	1
2	Increase in average annual air temperature	5	2	3	4	14	4
3	Increasing heat wave repeatability	1	6	4	2	13	3
4	Increase in frequency of squalistic wind (hurricanes) amplification	6	6	5	1	18	5
5	Average increase in rainfall	2	4	2	2	10	2
6	Declining and earlier onset of spring flooding in rivers	7	7	8	5	27	7
7	Increasing frequency of low tides and heavy rainfall in summer	4	5	4	1	14	4
8	Rising sea level in the Baltic Sea increases the frequency of salt water flow into the Curonian Lagoon	8	3	6	5	22	6
9	Absence of snow, ice and frost	6	8	7	6	27	7
10	Desertification (natural area crawl)	7	3	5	7	22	6
11	Change of habitats of dangerous pathogens	6	2	3	3	14	4

Results and Discussion

A questionnaire survey was used to conduct the study. Respondents were selected as the target groups whose activities are directly related to the territory of the Nemunas Delta. They are farmers (23), owners of tourism and rural homesteads (14) and heads of rural community organizations (11). Experts (6 people) also participated in the survey: Head of Silute (Šilutė) Life Protection Inspectorate; Head of the Nemunas Delta Regional park administration; Director of Silute Forest Enterprise; Head of JSC ‘Silutes polderiai’;

Head of the Department of Rural Affairs and Planning and Development of Silute District municipality.

Table 1 presents a hierarchical analysis of potential climate change impacts in the Nemunas Delta.

The data in the table show different views of farmers, farmsteads and experts. This is determined by the nature of the respondents’ activities and their importance. According to general respondents, the most problematic would be the increase of recurrence of dangerous natural phenomena, the average increase of precipitation and the increase of heat wave repeatability.

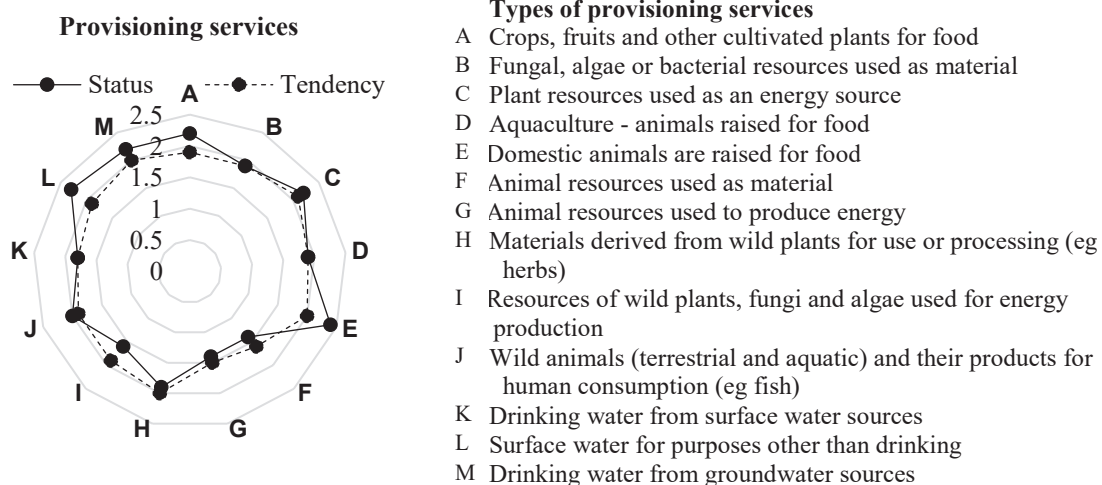


Figure 3. Assessment of the status and trends of provisioning services.

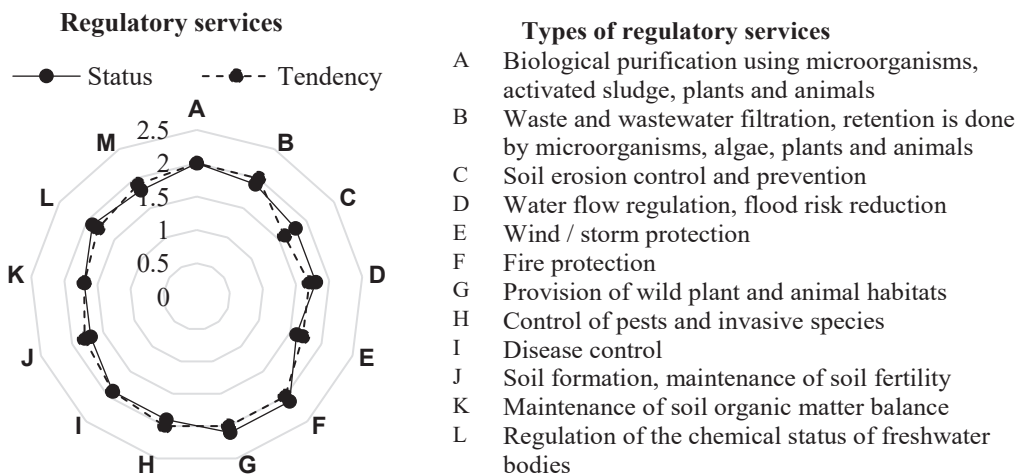


Figure 4. Assessment of the status and trends of regulatory services.

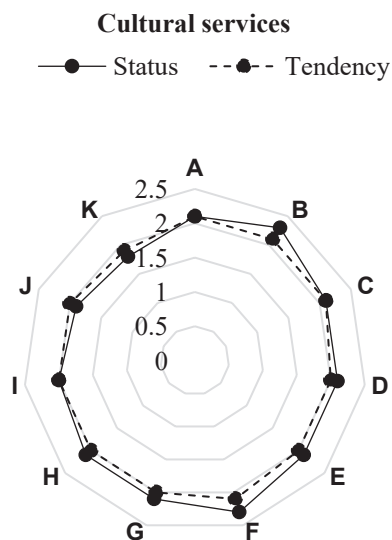
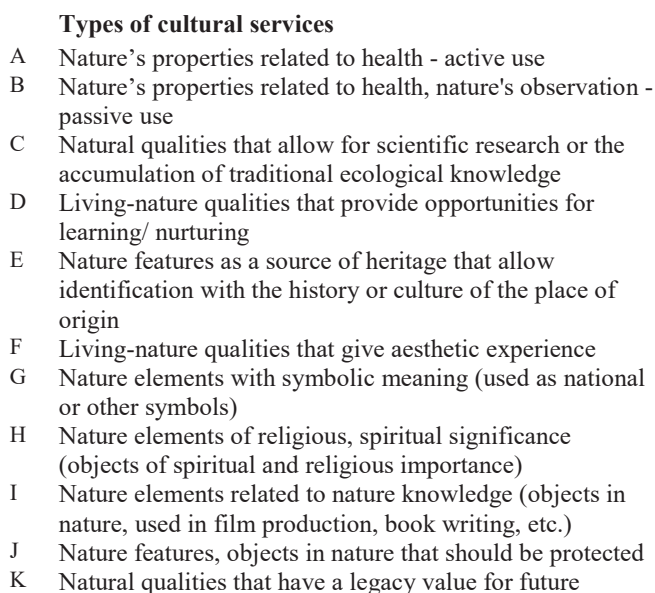


Figure 5. Evaluation of the status and trends of cultural services.

The study of the status and trends of the Nemunas Delta ecosystem services is based on an assessment of respondents' attitudes towards the status and trends of ecosystem provision, regulation, and cultural services (General International Classification of Ecosystem Services). The scale of ecosystem services was rated as good, 3, medium 2 and bad 1; trends: improving – 3; neutral – 2; getting worse – 1.

Respondents views of the state and trends of ecosystem provision, regulation, and cultural services are presented in Figures 3, 4, and 5.

The figures summarize the results of the evaluation of ecosystem services of all respondents. However, some respondents differed in their assessment.

Farmers, tourism homesteads and community organizations ranked the types of welfare services

best as 'domesticated livestock', 'drinking water from groundwater sources'. The worst-case status was mentioned by the respondents in question as 'animal resources used as material' (eg. wool) and 'animal resources used for energy production' (eg. plowing horses). 'Plant resources used as a source of energy' (eg willow biofuels, straw) and 'crops, fruits and other cultivated plants for food' were the best rated by experts. Worst of all are the 'plant, mushroom and algae resources used for energy production'.

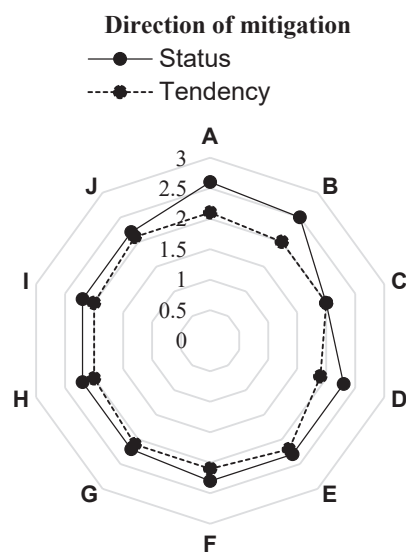
Farmers, tourists and community organizations were the most likely to appreciate the status of regulatory services as 'wildlife and animal habitat protection' and 'fire protection'. Worst of all are 'water flow regulation, flood risk reduction' and 'soil

erosion control and prevention'. Experts ranked the type of regulatory service as 'biological purification using microorganisms, activated sludge, plants and animals', and worst 'wind/storm protection'.

The condition of cultural services was evaluated similarly by all respondents: best of all – 'nature features that enable health, nature monitoring – passive use' and 'life features that provide aesthetic experience'; worst of all, 'natural features that have a heritage value (objects that future generations could use or enjoy)' and 'natural properties as a source of heritage to identify with the history or culture of the place of origin'.

The status of relevance of the measures envisaged in the European Commission document and trends in the development of ecosystem services in the area of the Nemunas Delta were analyzed for the evaluation of the directions of management of the consequences of climate change. Scale of rating, conditions: relevant – 3; neither yes/no – 2; not relevant – 1, trend: expected – 3; doubtful – 2; unforeseen – 1.

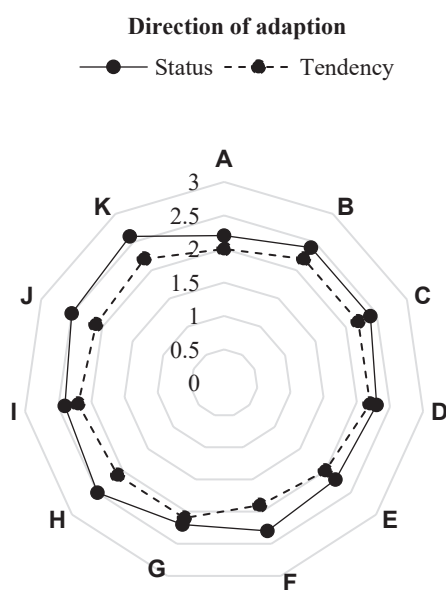
The sixth, seventh and eighth figures summarize the assessment of the relevance status and prognostic tendencies of the management measures of the focus group survey on the consequences of climate change in the Nemunas Delta.



Mitigation measures

- A To develop new and improve existing state road infrastructure, or part thereof, which consists of paved roads
- B Renewal and development of transport infrastructure and improvement of the environment and safety
- C To promote the collection and use of biogas for energy production and to reduce methane emissions
- D Implement waste management system management and waste incineration projects
- E Encourage companies to increase their use of renewable energy sources by co-financing projects
- F To promote the co-generation of low-power biofuels
- G Forest management, fire protection, prevention of natural disasters, diseases and pests, conservation and breeding of forest genetic resources
- H To promote the cultivation of new economically valuable, productive, bio-resistant forests on private land
- I Encourage the acquisition of machinery and equipment for the production of wood-based biofuels
- J Purchase / modernization of municipal waste

Figure 6. Assessing the effects of climate change on mitigation management.



Direction of adaption

- A Implement projects to strengthen environmental monitoring and control
- B Implement agri-environment programs
- C To investigate the agrochemical properties of soil
- D Implementation of management measures for the Curonian Lagoon and the Lower Nemunas River
- E Implement biodiversity protection projects
- F To implement investments that enhance the resilience and environmental value of forest ecosystems
- G Restoring forestry potential and introducing prevention measures against fires, natural disasters, pests and diseases and climate change-related events
- H To carry out maintenance and repair of forest road and drainage system equipment, to install and maintain forest recreational, environmental and scientific objects
- I Implement water resource management and protection, water supply and wastewater management projects
- J Implement projects to improve the status of surface water bodies
- K Implement flood risk management projects

Figure 7. Assessing the effects of climate change on management of adaption.

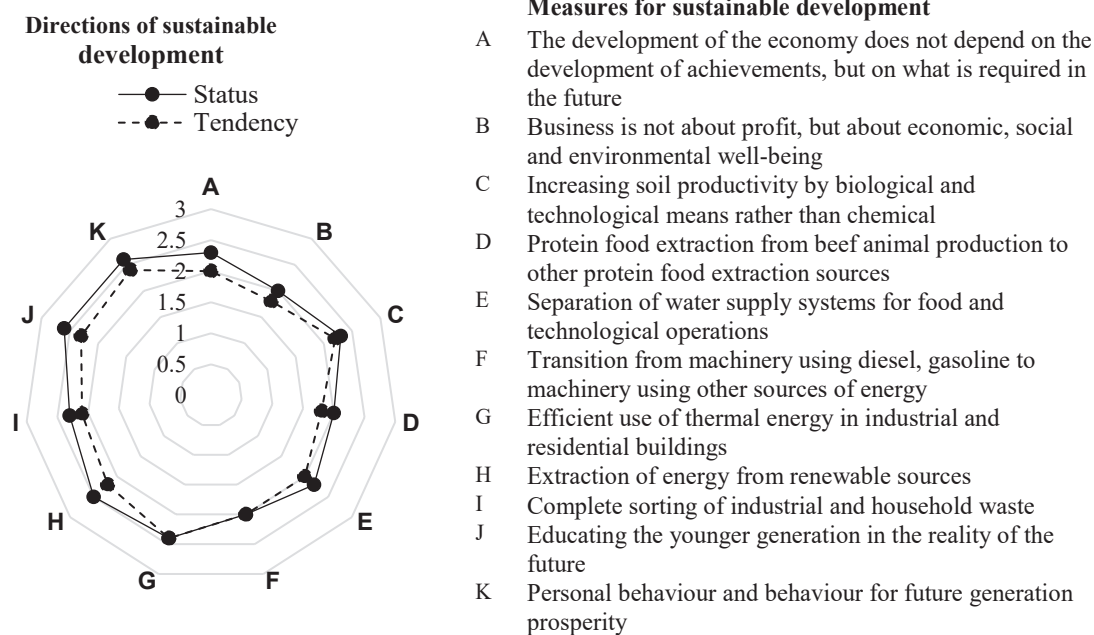


Figure 8. Assessing the consequences of climate change for sustainable development.

Summarized survey data of respondents indicate that:

- *Public road infrastructure, or part of it consisting of asphalt roads, ‘implementing waste management system management and waste incineration projects’ and ‘upgrading and developing transport infrastructure’ and ‘improving environmental protection and safety’.* At the very least, *‘capture and use of biogas to reduce methane emissions for energy production’ and ‘promote the acquisition of machinery and equipment for the production of wood-based biofuels’;*
- The most relevant in the direction of adaptation are *‘water resource management and protection’ and ‘water supply and wastewater management’, ‘improvement of surface water bodies’ and ‘flood risk management projects’.* Less relevant are *‘implementation of environmental monitoring and control projects’ and ‘implementation of forestry potential and prevention measures against fires, natural disasters, pests and diseases’;*
- Respondents attribute the most urgent measures to managing the consequences of climate change in the direction of sustainable development – *‘energy from renewable sources’, ‘educating the younger generation by changing the way education is organized in the future’ and ‘personal behaviour and behaviour for future generations’.* At the very least, *‘business is not about profit, but about economic and social well-being’ and ‘protein-*

based food transition from livestock farming to other sources of protein-based food’.

- Overall, the direction of managing the consequences of climate change is more or less relevant, but implementation trends in all directions are questionable in most areas.

Summary of Research Results

Today, in the context of global change, uncertainty and complexity are shaping a new developmental biology, similar in complexity to biological systems, which prevents the development of ecosystem services from being controlled by conventional means. This requires a review of traditional competencies and the shaping of current competencies for future well-being, reflecting outstanding competencies, without diminishing the future potential of human well-being.

Development opportunities could be described in two scenarios – waiting for the future and acting for the future.

Based on the *chronos* (time) tops (Figure 2), three directions of ecosystem services development in the Nemunas Delta can be distinguished:

- The development of ecosystem services in the short term, mitigating or reducing the scale of climate change problems in the present, as a consequence of past socio-economic and socio-cultural assumptions;
- Developing ecosystem services in the medium term, adapting to the potential consequences of climate change, and shaping the future socio-cultural fabric of community life that guarantees well-being of population;

- The long-term development of ecosystem services is based on sustainable development, where each sector, private or public or non-governmental, pursuing different goals serves the common interest, forming a new, different picture for the future.

Modern business has gone beyond the economic sample alone. This poses new challenges for innovation, entrepreneurship, competitiveness, sustainability and systematisation. Therefore, one must refrain from strictly focusing on one type of resource - finance, and introducing a series of different operational management systems that combine social, cultural, economic, intellectual, ecological and similar factors.

Conclusions

1. The development of ecosystem services in terms of global change has to do with: heritage management, mitigating the effects of climate change in the present-past relationship; intergenerational coherence management, adapting to the potential consequences of climate change in the present-future relationship; with sustainable development forming a new socio-cultural and socio-economic nexus in the future-past relationship, capable of synchronizing with the pace of change.

2. Empirical research has shown that respondents look at global climate change quite disconnectedly as if they were not concerned. They associate the development of ecosystem services in the Nemunas Delta, largely with mitigation of the potential consequences of climate change, with little adaptation to climate change and with little to no sustainable development. This suggests that, while the climate change management measures envisaged by the European Commission are positive, the commitment to them in developing ecosystem services in the Nemunas Delta is poor.
3. The change in natural and artificial processes indicates that we are on the verge of global change, turbulence, as old performance management systems stagnate and new ones are still in a state of birth. Thus, not only the value-added production process but also the process of change of performance management tools becomes the central axis.

Acknowledgements

Preparation of this paper was supported by funding from European Social Fund (project No 09.3.3-LMT-K-712-01-0178) under grant agreement with the Research Council of Lithuania (LMTLT).

References

- Stoffleth, D. (2015). *A Short History of Sustainable of Development*. Retrieved September 10, 2019, from <http://rethinkingprosperity.org/a-short-history-of-sustainable-development/>.
- Common International Classification of Ecosystem Services* (2013). European Environment Agency (EEA) Retrieved July 10, 2019, from <https://cices.eu/>.
- Grigaliūnienė, S. (2000). *Professional management*. Kaunas: VDU.
- Climate change mitigation and adaptation climate change guidelines for municipalities (2017). Vilnius, Association of Lithuanian Municipalities.
- Communication from the Commission – Europe 2020 A strategy for smart, sustainable and inclusive growth (2010). Retrieved September 10, 2019, from <http://ukmin.lrv.lt/uploads/ukmin/documents/files/Strategija%202020%20LT.pdf>.
- National Climate Change Policy Strategy (2012). SEIMAS OF THE REPUBLIC OF LITHUANIA. Retrieved August 8, 2019, from <https://e.seimas.lrs.lt/portal/legalAct/lt/TAP/71f17ca2081f11e8802fc9918087744d?jfwid=-fa58gt41z>.
- Константинов, П.И. (2018). *Изменение климата. Реальность, предубеждение, негативные последствия. (Climate change. Reality, prejudice, negative consequences)*. Retrieved August 10, 2019, from <https://drive.google.com/drive/folders/1KP4sRaIUNDYhBXb4GZBQm2pepX3AzKPs?ogsrc=32>. (in Russian).
- Melnikas, B. (2002). *Transformations*. Vilnius: Vaga.
- Schwab, K. (2018). *Management of the Fourth Industrial Revolution*. Vilnius: Vaga.
- Мескон, М., Альберт, М., & Хедоури, Ф. (2004). *Основы управления. (Basics of Management)*. Moscow: Delo. (in Russian).
- Щедровицкий, П.Г. (1993). *Экономические формы организации бизнеса и современные предпринимательские стратегии. (Economic forms of business organization and modern entrepreneurial strategies)*. Retrieved November 10, 2019, from <https://shchedrovitskiy.com/formi-hozyaistva-i-predprinima.../>. (in Russian).

DEVELOPMENT OF SUSTAINABLE DISTRIBUTION LOGISTICS SYSTEM

Rolandas Drejeris, *Mindaugas Samuolaitis

Vytautas Magnus University, Lithuania

*Corresponding author's email: mindaugas.samuolaitis@vdu.lt

Abstract

Sustainable development is playing an increasingly important role in today's society, and it is essential for companies seeking to meet the needs of the market to pay increasing attention to the application of sustainable development principles in their operations. The enterprise logistics system is one of the essential activities ensuring the company's competitiveness, which ensures timely production and quality of customer service. However, in order to integrate the principles of sustainable development into the company's logistics system, it is necessary to develop a model that identifies the impact of sustainability on each factor of the logistics system. The paper analyses the impact of sustainable development on distribution logistics to determine which activities in distribution logistics are most responsive to sustainable development and can help determine the level of corporate sustainability. The main purpose of the model, presented in the paper, is to help the business sector integrate sustainable development principles effectively in distribution logistics, taking into account the significance of ongoing factors in the system for sustainability.

Key words: logistics system, sustainability, distribution.

Introduction

Proper management of logistics processes promotes the development of various sectors not only at regional or national level but also at international level. A responsible approach to logistics processes is a prerequisite for implementing the basic principles of sustainable development from the supplier to the end user. Process optimization and sustainable development are becoming an integral part of logistics. Responsible logistics is no longer just a term in today's society, but one of the key factors in ensuring market competitiveness.

Logistics chain management is extensively analyzed in the scientific works of foreign and Lithuanian authors; however, the creation and effective management of an offensive logistics chain is becoming increasingly important. Guidelines on how to achieve greater sustainability in order to improve economic performance are still widely debated by authors and practice-oriented minds. These guidelines could be later used by start-ups and well developed companies concerned about environmental sustainability. The absence of a universal model detailing implementation of actions directed towards sustainability of logistics processes is one of the greatest issues currently faced by both business theorists and practitioners. As mentioned above some scientific works for sustainable logistics actions exist, but methodological potential according to systematical approach is especially poor. The high demand for a solution to this problem and its practical and scientific topicality motivated us to present research into this field. The aim of the research is, firstly, to examine the relevance of sustainable logistics as a component of sustainable activity and, secondly, to present a model which would determine possible routes for implementing commonly accepted logistical actions associated with the sustainable

development. The model would additionally serve as an instrument to assess the readiness and possibility to develop logistical actions in general for any logistics corporate sustainable activity.

Integrating sustainability procedures into the enterprise logistics system is an important enough factor in increasing the competitiveness of logistics enterprises. Proper management and optimization of logistics processes helps a company to compete both at national and international levels. One of the most important aspects is providing quality logistics services (Chen, Chang, & Lai, 2009; Huang, Wang, & Xue, 2012).

A sustainable logistics chain is understood as an activity that is consistent with the principles of sustainable development and ensures the long-term sustainability of the company. And its creation may require tangible and intangible investments.

Problem of the research. Quality of distribution system organization is an important part of the logistics chain, but as a result of sustainable business development at national and international levels, the question arises how to organize distribution logistics to meet the maximum requirements of sustainable business? The absence of an instrument for solving this task is topical for both theorists and practitioners.

Aim of the research. The aim of the paper is developing a model for sustainable distribution logistics that will help the company successfully integrate sustainability principles into distribution logistics.

Objectives of the research:

- to review the theoretical aspects of distribution logistics system and its main components,
- to analyze importance of sustainability integration in distribution logistics system,
- to create theoretical and sustainable distribution logistics model.

Materials and Methods

The solution to this problem is complex and requires a systematic approach. A systemic approach does not mean solving all aspects of a complex problem at once, but it does allow us to see the big picture: to break it down into separate components, to analyze them, to highlight the most important, and finally to integrate them into a whole. So methods of modeling are required. To achieve the aim of the article through the analysis of researchers' opinions, it is also necessary to apply methods of assessment, systematisation, and comparison of information, to select the most important information describing the sustainability actions of logistics, to highlight the relationships between the logistic aspects of sustainability, to evaluate some processes of the logistics product in terms of sustainability, to clarify and present arguments highlighting the importance of the logistics aspect in sustainable business activity, to reject inappropriate arguments, to identify links between the arguments, and, based on the information, to form a new Model of Development for Sustainable Distribution system. Creation the new and innovative model was an aim of the article. For complete clarity operations of the model as well was necessary to reason consistency of the suggested model components and even their content. So, Thus, the operation of the model becomes completely clear to each of its possible users.

Results and Discussion

Requirement for the Model of Development for Sustainable Distribution System

When designing a model, it is necessary to identify the key components of the model and the factors that affect distribution logistics.

Various ways of optimizing logistics processes are described in the scientific literature. Price, customers demand, logistics service and sustainability (Lichocik & Sadowski, 2013; Hadas, Stachowiak, & Cyplik, 2014; Matwiejczuk, 2013; Pehlivanova, 2011) must be analyzed as most important aspects. These authors deal with different aspects in their work, but all these aspects influence the optimization of logistics processes in different sectors.

Optimization issues are also addressed in supply chain management. Logistics and supply chain analysis is becoming a widely accepted prerequisite for business sustainability. Bertasius (2007) presents evaluation of integrated management system, and Kaplan & Anderson (2004) present the analysis and application of time-based management methods of enterprise performance evaluation. The presented models identify the main elements of the logistics system, but in order to develop a model for the appropriate part of the distribution logistics system,

the warehousing and transportation of the finished product must be analyzed.

In the scientific literature, Stankevičiūtė & Savanevičienė (2013) analyze the effectiveness factors of corporate social responsibility impact and their significance for modern society.

Halsan (2007) examines the main human factors that have the greatest impact on the development of corporate social responsibility in the business sector. A study by Hall, Matos, and Silvestre (2012) analyzes the need for companies to invest in a sustainable supply chain.

The authors extensively analyze the optimization of logistics processes in terms of added value, cost, quality, customer satisfaction and other factors efficiency (Lichocik & Sadowski, 2013). It also analyzes the organization of quality services and their impact on the implementation of social responsibility objectives (Hadas, Stachowiak, & Cyplik, 2014) and comparing the quality of logistics services provides an opportunity to improve this process (Kilibarda, Zečević, & Vidovic, 2012). Customer satisfaction with logistics service quality has a significant impact on the sustainability of companies (Lisinska-Kusnierz & Gajewska, 2014).

Various models are being developed to increase the efficiency of logistics operations. One of such models is the model of logistic enterprise and sustainable development (Vasiliauskas, Zinkeviciute, & Simonyte, 2013), which helps to better understand the influence of sustainable development on increasing the efficiency of enterprise activities. Juščius & Jonikas (2013) in their research aimed to reveal the influence of corporate social responsibility integration on the creation of value added in companies.

Every business sector needs to be very well understood and know how to manage the logistics chain, since the quality of its processes depends on the organization's quality existence and competitiveness (Matwiejczuk, 2013; Pehlivanova, 2011, Weijers, Glockner, & Pieters, 2012) and successful risk management (Vikulov & Burit, 2014).

Based on the analysis of scientific literature, a model is being developed in which key elements of distribution logistics are tested through key sustainability dimensions. The purpose of the model is to help the business enterprise properly analyze, evaluate and develop a sustainable distribution logistics chain.

Creation of the Model of Development of Sustainable Distribution System

In developing a sustainable distribution logistics chain model, the key elements of distribution logistics related to warehousing and transportation are tested through sustainability dimensions to identify the level

of sustainability and improvement potential of the company.

The presented model of the factors of sustainable distribution logistics system design the process of the distribution system in order to improve the organization of the company's logistics activities taking into account the influence of sustainability on each process factor.

The developed model analyzes the key drivers of the distribution process in order to identify opportunities for their improvement with respect to the integrity coherence. It means that mentioning all the factors and their impact to the objects is necessary. At the beginning, some constant general indicators have to be determined, then possibilities assessment for improvement logistical actions in the area of sustainability is preferable.

Systematizing the data in the first part will be used to analyze the distribution system of the companies' output and identify the opportunities for improvement, which is better to analyze further in the next part of the suggested paper. According to the mentioned ideas for model creating in the Figure 1, we present the model of Development of Sustainable Distribution system. The model of Development of Sustainable Distribution system is presented in Figure 1.

Action for determination general constant indicators

In order to conduct a comprehensive analysis of the distribution system in terms of sustainability, the first step is to gather information about the elements of the enterprise distribution system. The key elements of a distribution system can be divided into two environments: storage and transportation. These environments are made up of 6 essential components that are presented in part I:

- warehousing object;
- warehousing infrastructure;
- warehousing technology;
- transportation object (cargo);
- transport infrastructure;
- vehicles.

When analyzing the storage process, it should be noted that the quantity and nature of storage factors depend on:

- the quantity of product marketed;
- storage network;
- number of intermediaries;
- storage space;
- warehousing techniques and technologies;
- customer / user type and stockpiling;
- additional services provided (sorting, packing, customs, transit, etc.)

In the storage environment, three components of the distribution system are analyzed: storage object, storage infrastructure and work organization, warehouse and technology. Warehousing object –

a stock in a warehouse for sale. This object in the distribution system is affected by different factors depending on the specifics of the company and the organization of work. The information collected is required to organize the storage of the facility: cargo volume, weight, space occupied, transferability, environmental and equivalent to the adaptability of the storage environment. Storage infrastructure is necessary information to identify current and potential factors involved in the organization of the entire process. Warehouse internal infrastructure, management solutions depend on the functionality of the whole system. Information on the warehouse size, area, adaptability, layout and integrity is collected. Taking into account the infrastructural components, the work inside the warehouse is organized and the factors that take place there are identified: packaging, sorting, storage, assembly, transportation inside the warehouse, documentation, etc. Warehouse and technology – analysis of warehouse type, its applicability, geographic environment and accessibility, cargo handling technologies and warehouse management techniques and technologies.

Factors analyzed in the transport environment relate to the organization of the transport system:

- type of transport;
- stowage equipment;
- adaptability of the vehicle;
- vehicle technology and technology;
- IT related to vehicles;
- transport route, etc.

The cyclical structure of the model shows that actions of sustainability have to be permanent in any logistics company. In other parts of the paper detailed explanation of the processes for sustainability is presented.

Three components have to be analyzed in the transport environment: transport object (cargo), transport infrastructure and vehicle. Transport object (cargo) is the main element on which the choice of vehicle, adaptability of machinery, work organization and other functional elements depend. In organizing work on the subject of the shipment, consideration shall be given to pre-loading factors, loading factors, factors occurring during transport, factors occurring at unloading. The choice of vehicle and route planning, the organization of the driver's work and additional checks during cargo transportation depend on the weight and volume consistency of the object and other components. Transport infrastructure determines availability of cargo transportation, what technologies are needed, possibilities of cargo handling, suitability of communication, applicability of IT technologies, etc. 'Vehicle' means the adaptability of a vehicle to the carriage of goods, the technology and IT in-vehicle, its equivalence to the

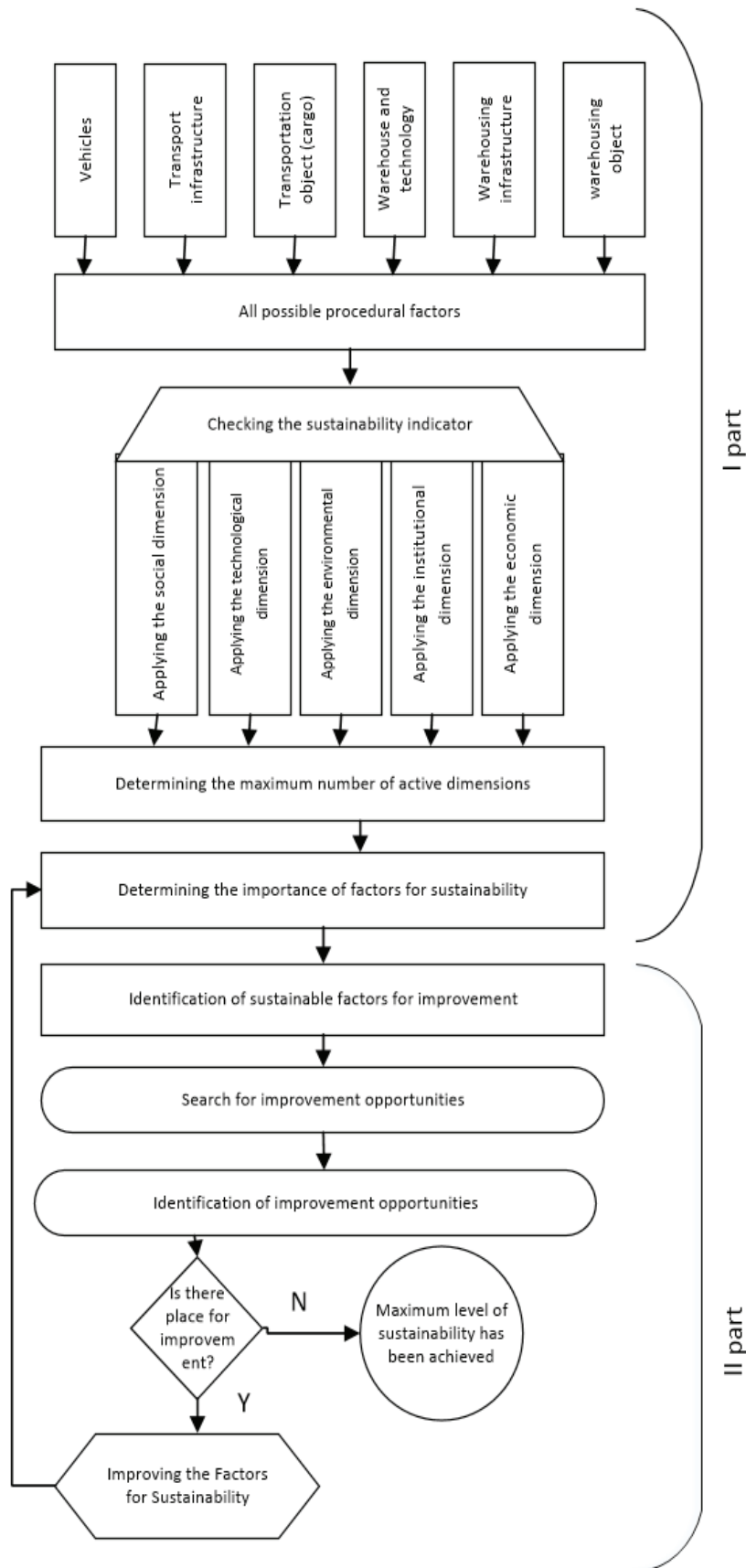


Figure 1. Model of Development for Sustainable Distribution system.

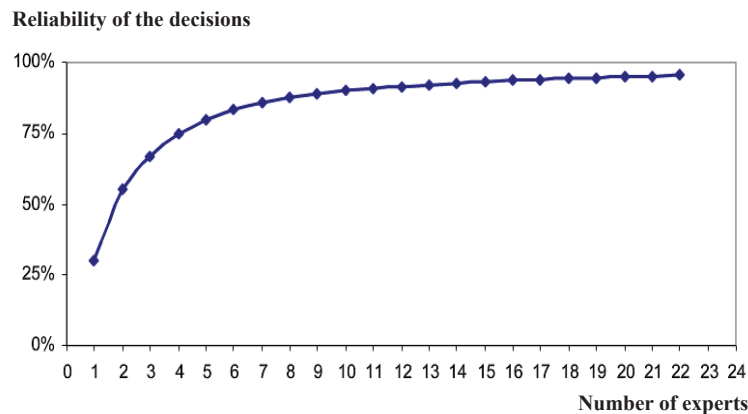


Figure 2. The decision reliability dependence on number of experts (Wright *et al.*, 2019).

requirements of the legal environment in which the vehicle is transported.

In the first part, by analyzing the ongoing factors of all the essential components of the distribution system, a list of all possible factors is created, which is then analyzed, evaluated and refined. It should be noted that the key components of distribution logistics in the logistics process are interdependent, so it is clearly distinguished which factors are appropriate for one component and which are practically impossible for the other. Distribution logistics factors and their actions are fully integrated and function systematically. Both storage and transportation factors are determined by the object being stored and transported, so full object analysis is required to identify the specifics of work organization.

By systematizing information on procedural factors, their sustainability is scrutinized and corresponds to 5 dimensions of sustainability: *social, technological, environmental, institutional and economic*.

Each factor may be fully consistent and integral with all five dimensions, but may not be integral with all of them. There must be *determining the maximum number of active dimensions*, which identifies each factor to how many dimensions it can match. This is essential for assessing the coherence of factors. Failure to identify this figure will result in a non-validation indicator, as some factors may not be measurable due to their specificity.

After identifying the factors that are sustainable and need to be improved, it is necessary to determine the significance of the factors for sustainability and company processes. For this step, expert evaluation is used and all procedural factors are ranked according to their significance coefficients from maximum to minimum significance for coherence and for the company and a generalized list of systematic information is derived. This list is needed to implement the next steps in the process, prioritizing the steps to be taken to achieve the maximum cohesive effect

within the company in the *Part II of the model*.

Evaluation of factors in terms of sustainability

When conducting factor assessment, the factors that occur primarily within the company are categorized as cohesive and refinement factors for distribution logistics. Sustainability is determined in the context of sustainable factors. After identifying the factors to be improved, the model looks for opportunities for factor improvement and assesses the feasibility of factor improvement in the current situation, in accordance with sustainability principles.

The search for opportunities creates a list of improvement opportunities and identifies, and evaluates the improvement opportunity company based on a sustainable system of information on the significance of the factors. This is done based on the company's ability to perform improvement actions at the current situation. Significance of the factors has to be determined by expert method. Number of experts influences reliability of the final decision. We suggest using the scheme (Figure 2) for determination of the best number of experts, according to which we think that 7-8 experts are enough for a reliable decision.

Expert requirements also need to be established: logistics experience, understanding of sustainability, achievements in these areas.

Prior to their assessment, it was important to establish criteria for the assessment in order that the assessment could be as objective as possible (Drejeris & Miceikiene, 2018). To do this, we proposed a scale of 100 points and total estimates are calculated as follows (Drejeris & Oželienė, 2019):

$$W_i = \frac{\sum_{e=1}^n W_{ie}}{n}, \quad i = 1, m \quad (1)$$

where W_{ie} is an estimate of the i -th question by the e -th expert, n is the number of experts and W_i is the sum of all i question estimates by all experts.

The equation below is used to establish the relative importance of the criteria (Drejeris & Oželienė, 2019):

$$n_i = \frac{W_i}{\sum_{i=1}^m W_i}, \quad i = \overline{1, m}, \quad (2)$$

In this case the sum of criteria importance will always equal one:

$$\sum_{i=1}^m n_i = 1, \quad (3)$$

If the result is different, there must be a calculation error.

The results of the experts' assessment are better to present in the form of table.

Then, the assessment of factors' value according to possibilities for sustainability has to be calculated by the following formula (Drejeris & Oželienė, 2020):

$$T = \sum_{i=1}^j \eta_i K_{ij}, \quad (4)$$

Where T – total value of factors according to possibilities to be sustainable, K – value of every factor in a 10-point system.

Once the potential for improvement is identified, improvement of the identified factors in terms of sustainability is initiated. After completing the improvement procedures, the process goes back to the beginning of the second part to determine the level of sustainability of the company.

If there is no way for improvement in the current situation, then maximum level of sustainability has been achieved.

The whole model is created to help business to identify current situation of sustainability of

distribution logistics and how to manage improvement of it.

Conclusions

1. Distribution logistics management is one of the core activities of a company to increase its competitiveness. Improper distribution of the logistics chain management can cause the company to suffer both financial and customer losses. The qualitative aspect of distribution logistics is extensively analyzed in the scientific literature, but in order to ensure the quality, increasing attention is paid to the sustainability of factors.
2. Distribution logistics chain management sustainability is most clearly seen and analyzed by customers. Distribution logistics activities are carried out up to the customer, and as the impact of sustainability in today's society becomes one of the customer's evaluation criteria, the increasing influence on the competitiveness of the company derives from its ability to deliver sustainable distribution logistics.
3. The developed theoretical model of sustainable distribution logistics is designed for self-assessment and development of regular distribution logistics. For the fully functioning model, it is necessary to conduct a sustainability assessment of all distribution logistics factors and identify opportunities for their improvement. Emerging scholarly topic is discussed in a carefully crafted and persuasively argued position before active experimentation and other forms of empirical assessment. Thus, our further research will focus on the application of the proposed model in various industrial sectors.

References

- Bertasius, D. (2007). Evaluation of the Industrial Enterprises Management Systems Effectiveness. *Technological and Economic Development of Economy*, 13(1), 3–9.
- Chen, K., Chang, C., & Lai, C. (2009). Service quality gaps of business customers in the shipping industry. *Transportation Research Part E*, 45, 222–237.
- Drejeris, R., & Miceikiene, A. (2018). Multi-Criteria Measurement of sustainable innovativeness in farming organisations: evidence from Lithuania. *Sustainability*. Vol. 10, No. 9, pp. 33–47.
- Drejeris, R., & Oželienė, D. (2019). Modeling environmental actions of corporate sustainable activity: evidence from Lithuania. *Central European business review*. Vol. 8, No. 5, pp. 68–93.
- Hadas, L., Stachowiak, A., & Cyplik, P. (2014). Production-logistic system in the aspect of strategies for production planning and control and for logistic customer service. *LogForum*.
- Hall, J., Matos, S., & Silvestre, B. (2012). Understanding why firms should invest in sustainable supply chains: a complexity approach. *International Journal of Production Research*. Vol. 50, No. 5, 1 March 2012, pp. 1332–1348. ISSN 0020–7543 print/ISSN 1366–588X online.
- Halsan, A. (2007). Human resource development and organizational values. *Journal of European Industrial Training*, 31(6), 435–448.
- Huang, B., Wang, T., & Xue, X. (2012). Service-selecting approach based on domain-specified 'Quality of Service' model and its application in logistics. *The Service Industries Journal*, 32 (9), 1571–1588.
- Jušcius, V., & Jonikas, D. (2013). Integration of CSR into Value Creation Chain: Conceptual Framework. *Inžinerinė ekonomika*, 24(1), pp. 63–70.

- Kaplan, R.S., & Anderson, S.R. (2004). Time-based activity-based costing. *Harvard Review*, 131-138.
- Lichocik, G., & Sadowski, A. (2013). Efficiency of supply chain management. Strategic and operational approach. *Scientific Journal of Logistics*. LogForum 9 (2), pp. 119–125. ISSN 1895-2038.
- Lisinska-Kusnierz, M., & Gajewska, M. (2014). Customer satisfaction with the quality of the logistic services. *Scientific Journal of Logistic*. LogForum 10 (1), pp. 13–19. ISSN 1895-2038.
- Matwiejczuk, R. (2013). Logistic potentials in business competitive advantage creation. *Scientific Journal of Logistic*. LogForum 9 (4), pp. 265–275. ISSN 1895-2038.
- Pehlivanova, T. (2011). Optimization of management of logistic systems in agriculture. *Trakia Journal of Sciences*, Vol. 9, No. 4, pp. 16–19. ISSN 1313-7069.
- Stankevičiūtė, Ž., & Savanevičienė, A. (2013). Sustainability as a concept for human resource management. *Ekonomika ir vadyba- Economics and management* (2), pp. 837–846. ISSN 2029-9338.
- Vasiliauskas, A.V., Zinkevičiute, V., & Simonyte, E. (2013). Implementation of the concept of green logistics referring to it applications for road freight transport enterprises. *Business: theory and practice*. 14 (1), pp. 43–50. DOI: 10.3846/btp.2013.05.
- Wright, G., Cairns, G., O'Brien, F., & Goodwin, P. (2019). Scenario analysis to support decision making in addressing wicked problems: Pitfalls and potential. *European Journal of Operational Research*. 278(1), pp. 3–19.
- Weijers, S., Glockner, H., & Pieters, R. (2012). Logistic service providers and sustainable physical distribution. *Scientific Journal of Logistic*. LogForum 8 (2), pp. 157–165. ISSN 1895-2038.
- Vikulov, V., & Burit, A. (2014). Risk assessment and management logistics chains. *Scientific Journal of Logistic*. LogForum 10 (1), pp. 43–49. ISSN 1895-2038.

RESILIENCE IN AGRICULTURE: HOW CAN CAP DIRECT PAYMENTS IMPACT IT?

*Agnė Žičkienė

Lithuanian Institute of Agrarian Economics, Lithuania

*Corresponding author's email: agne.zickiene@laei.lt

Abstract

The increasing frequency and magnitude of adverse meteorological events together with the growing uncertainty in the upcoming future pose more and more challenges to agriculture. Therefore, the future sustainability of agriculture will increasingly depend on its resilience, i.e. the capacity to withstand various perturbations and to recover from them. The direct payment (DP) system of the EU Common agricultural policy (CAP) is the most financed EU support scheme for agriculture; however, research on its impact on the important phenomena of resilience is scarce and fragmented. In order to fill this gap, this paper offers an extensive overview of literature and a summarized list of factors that are mentioned most often as potentially influencing the agricultural resilience. Based on this, the possible impact of DP on agricultural resilience was analyzed. In this paper, it is argued that this impact is transferred mostly through changing farms' financial capabilities as well as farmers' attitudes and behavior, and is both positive and negative. Such phenomena as low crop insurance uptake and decrease in productivity may be due to the overcrowding effects of direct payments. These hypotheses are being tested in a survey, conducted in the meantime.

Key words: resilience, agriculture, CAP direct payments.

Introduction

Agricultural sector is exposed to various types of risks: economic, climatic, environmental, political, technological, etc. Several types of risks often turn out simultaneously, exacerbating each other's negative consequences. Besides that, agricultural markets are very specific, defined by high seasonality, long production cycles and short shelf-life, which make these markets especially vulnerable to various risks with significant repercussions on a wider scale. Although farmers have always been facing most of the above mentioned risks and have adapted to them more or less successfully, the speed of the ongoing changes, the increasing frequency and magnitude of adverse meteorological events, alongside with the growing uncertainty in upcoming future pose additional challenges threatening the long-term viability of agricultural systems as such. Therefore, numerous scientists (Almas & Campbell, 2012; Sawicka, 2019) emphasize that future sustainability of agriculture will increasingly depend on its capacity to withstand various perturbations and to recover from them, in other words – on resilience. Not surprisingly, resilience has been included as one of the priority goals in the upcoming agricultural support agenda of the 2021–2027 financial programming period of the European Union. However, the studies on the economic resilience in agriculture are scarce, fragmented and mainly focused on ecological rather than economical side of the system. The research on how the EU support schemes for agriculture impact the resilience of the sector, – whether these schemes contribute to or on the contrary, hinder resilience building, is especially limited. In order to fill this gap, this paper analyses what determines resilience of the agricultural sector as well as analyses direct and indirect ways in which EU direct payments can influence resilience of the agricultural sector.

Materials and Methods

This paper is built on the analysis and synthesis of scientific literature, legal documents and statistical data.

Up to date, two main perspectives on resilience can be found in economic literature: so-called 'equilibrium' approaches and the so-called 'non-equilibrium' or 'complex systems' approaches (Bristow & Healy, 2013). 'Equilibrium' approaches consider an economic system to be relatively simple, homogenous and stationary, finding itself in some kind of equilibrium or growth path that develops in linear, predictable way (Fagiolo, 2016). Systems themselves are usually studied on a single level, separately from their immediate environments, using equilibrium models and normal distribution-based statistics. In the framework of these 'equilibrium' approaches resilience is defined either as the ability of a system to 'bounce back', i.e. to return to a pre-shock equilibrium state or growth path it would have been in if the shock was absent (Fingleton *et al.*, 2012; Angulo, Mur, & Trivez, 2017), otherwise called engineering resilience, or as the ability to absorb the shocks that '...have the potential to throw it off its growth path but do not actually do so' (Wolman *et al.*, 2017), also known as ecological resilience. 'Non-equilibrium' or adaptive approaches are based on the theory of complex adaptive systems. These systems are characterized by heterogeneity, non-linear complex dynamics, continuous interaction with their environment and operation under a constant uncertainty and change. This complex non-linear dynamics challenge the whole idea of equilibrium, stating that complex adaptive systems are never in equilibrium. Therefore, a return to a previous stable state (equilibrium) after a disturbance may be neither possible (due to a constant change) nor desirable. Moreover, the seemingly stable

states can suddenly change and become entirely new ones, with different structure, controls and feedbacks (Bristow & Healy, 2013). Thus, resilience is not viewed as a return to some stable previous state, but rather as a dynamic, evolutionary capacity to adapt in response to perturbations (ibid).

In this paper, the latter approach to resilience is used, defining resilience of an agricultural sector as the capacity of this sector to withstand or recover from various (market, competitive, environmental, etc.) shocks, if necessary, by undergoing adaptive changes to its economic structures and social and institutional arrangements, so as to maintain its core functions (based on definitions proposed by Martin & Sunley, 2015). The core functions of the agricultural sector here are limited to the provision of private goods (production of affordable food and other bio-based resources, provision of income for farmers and farm workers, and assurance of farm viability), excluding the provision of public goods, since in most cases important trade-offs exist between those two groups of goods. It must also be noted that in this paper general resilience (as opposed to 'specified' resilience) is being explored, focusing on the capacity of a system to react to various kinds of shocks and perturbations, instead of dealing with a particular shock or particular aspect of the system that might be affected by that shock (Biggs *et al.*, 2012).

Determinants of resilience. There is a lot of research dedicated to finding out the factors determining the resilience of an economic system. However, this question is still open – there is no consensus neither on the set of factors potentially influencing resilience, nor on their significance, or on the idea if such universal factors (influencing resilience across time and space) can be determined on the whole.

Studies of resilience are performed at various levels – micro (individual, household, business, government agency), meso (individual sector, industry or market) and macro (operation of the economy, combination of all economic entities on a certain territory), and the greater share of those studies focus on system's features as determinants of resilience. Different authors identify different sets of such features influencing resilience. However, – one of the most analyzed aspects is the system's economic structure (Darnhofer *et al.*, 2010; Cabell & Oelofse, 2012; Martin & Sunley, 2015; Angulo, Mur, & Trivez, 2017). One of the most analyzed topics in this area is whether system's specialization or diversification leads to resilience. Many authors (Davies & Tonts, 2010; Doran & Fingleton, 2013) argue that diversification is a way to increase resilience. Their inferences are based on reasoning that since different types of industry, sectors, subsectors, elements, etc. have different characteristics (e.g. different (sub)

sectors have different elasticities of demand, different knowledge, labor and capital intensities, different export orientations, different production cycles, different vulnerabilities to various risks, etc.), the diversified system should be less susceptible to some particular shock than a specialized one. The former should also recover faster since it would have more options to act upon and more alternative ways to adapt and recover (Evans & Karecha, 2013). However, empirical evidence shows that diversified systems are not always more resilient than specialized ones (Martin *et al.*, 2016). Therefore, some scholars argue that it is not only the level of diversity or specialization that matters, but also how the elements in the system are interconnected as well as the availability of unspecific and uncommitted capacities that can be put to a variety of unforeseeable uses (Boshma, 2015).

The other factor, almost universally identified as having a very significant influence on system's resilience, is education of human agents of that particular system (Cabell & Oelofse, 2012; Martin & Sunley, 2015; Bristow & Healy, 2017). It is well-known that a well-qualified and skilled workforce contributes to higher productivity of businesses, and the higher the productivity of the firms the more resilient they are likely to be (Martin *et al.*, 2016). It also provides the local economy as a whole with greater scope for adapting out of major crises (ibid). Population age, entrepreneurship and people's attitudes and expectations are also considered as very important factors determining resilience of a system (Martin & Sunley, 2015; Obschonka *et al.*, 2016).

Other factors that various authors classify as having important impact on resilience can be grouped in several categories, corresponding to the economic, social, ecological and political dimensions of a system, analyzed at three levels (micro, meso and macro). Economic dimension comprises such factors as macroeconomic indicators (Angeon & Bates, 2015; Martin *et al.*, 2016), access to resources (Darnhofer, Fairweather, & Moller, 2010; Martin *et al.*, 2016; Wink *et al.*, 2018), infrastructure (Boto & Pandya-Lorch, 2013), export diversity (Angeon & Bates, 2015; Wink *et al.*, 2018; Morkūnas *et al.*, 2018) and business characteristics (Cabell & Oelofse, 2012; Wink *et al.*, 2018). Social factors encompass connections and networks (Martin & Sunley, 2015; Boschma, 2015; Sabatino, 2019) as well as social norms, values, customs and traditions (Biggs *et al.*, 2012; Martin & Sunley, 2015; Bristow & Healy, 2017). Legislative frameworks and government economic policies and support are important both, during the shock, as well as in periods before it (Boto & Pandya-Lorch, 2013; Angeon & Bates, 2015; Wink *et al.*, 2018). Ecological dimension covers such factors as landscape and biodiversity, soil quality, etc., which are especially

relevant for the resilience of the agricultural sector (Cabell & Oelofse, 2012; Altieri & Nicholls, 2017).

Empirical evidence shows, however, that despite very similar features of the two systems, their resilience may differ profoundly and standard macro-economic models struggle to account for resilience at the meso or macro levels (Martin *et al.*, 2016; Obschonka *et al.*, 2016). One of the main reasons of such a difference may be due to the neglect of human behavior and its role for resilience. However, human behavior is one of the core determinants of the resilience and many researchers agree on that (Martin & Sunley, 2015; Obschonka *et al.*, 2016; Wolman *et al.*, 2017). Almost all the developments at the macro level depend on the activities at the micro level and any outcome at the micro level depends on the human action or inaction, since inaction is also an action, the behavior of the myriad of economic agents before the shock and after it determines if the whole system will be resilient or not. Of course, the context and environmental conditions also matter but not by their mere existence – they matter as options of possible choices from which a human chooses which ones to exploit. A wide array of research (Martin & Sunley, 2015; Obschonka *et al.*, 2016) shows that regions subject to the same macroeconomic forces and having similar economic structure perform very differently. It is because with the same set of structural elements there is a huge set

of possible choices. Which ones would be selected depend first of all on the human agency (individual or collective). Recently behavior, especially particular types of it, is getting more and more attention by economists studying resilience. Although empirical findings are still quite scarce, many researchers tend to mention several behavior patterns that lead to resilience in multiple contexts, namely: creating and absorbing innovations (Darnhofer *et al.*, 2010; Martin & Sunley, 2015; Obschonka *et al.*, 2016; Bristow & Healy, 2017; Wink *et al.*, 2018), learning (increasing qualifications and improving skills) (Biggs *et al.*, 2012; Sellberg *et al.*, 2018), collaborating and cooperating (Cabell & Oelofse, 2012; Biggs *et al.*, 2012; Boschma, 2015; Martin *et al.*, 2016; Bristow & Healy, 2017; Sellberg *et al.*, 2018), managing risks (Marchall *et al.*, 2012; Boto & Pandya-Lorch, 2013; Linkov *et al.*, 2014; Martin *et al.*, 2016) participating (Cabell & Oelofse, 2012; Wink *et al.*, 2018; Sellberg *et al.*, 2018), sustainably managing resources (Darnhofer *et al.*, 2010; Cabell & Oelofse, 2012), and enabling polycentric governance (does not apply to micro level) (Biggs *et al.*, 2012).

Taking into account the research on resilience determinants provided above, it could be argued that resilience of the agricultural sector as a socio-economic system depends on the behavior of various agents interacting among each other inside the system as well as with other agents outside it by their behavior being

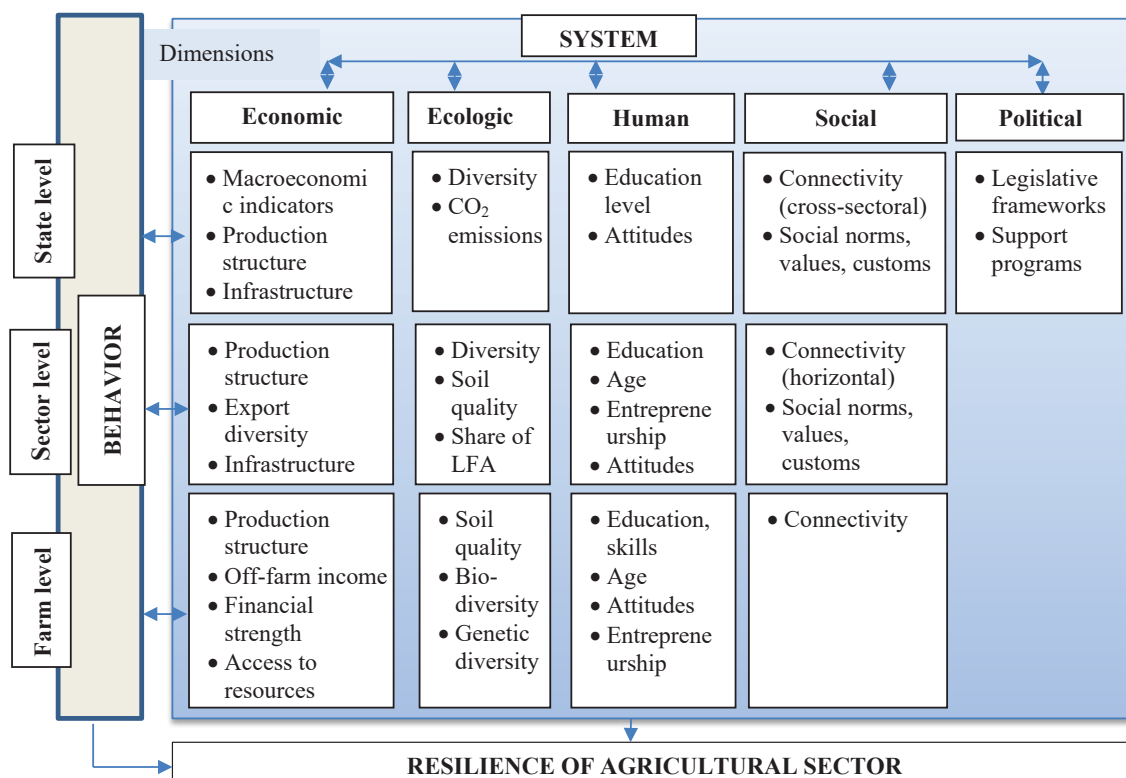


Figure 1. Factors, potentially determining resilience of the agricultural sector.

Source: compiled by the author.

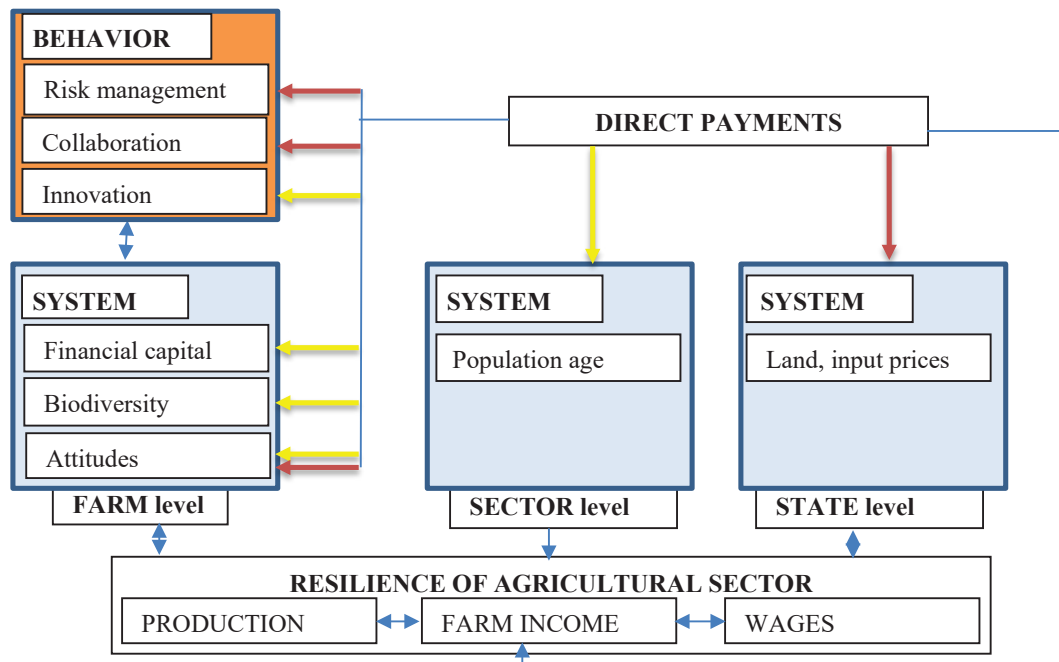


Figure 2. Model of CAP DP impact (yellow positive, red – negative) on the resilience of agricultural sector.
Source: compiled by the author.

reciprocally influenced by the system’s characteristics as well as each other’s actions (Figure 1).

Direct payments and their impact on resilience of agricultural sector. Direct payments (DP) are one of the main support measures of Common Agricultural Policy (CAP), accounting for more than 70% of total support for agriculture (and more than 26% of the whole EU budget) in 2014–2020 period. They represent around 30% of farm income (differing between farming types and different states) and are aimed at increasing and stabilizing farm income as well as supporting farmers to deliver a multiplicity of goods and services (Severini *et al.*, 2016).

However, even if DP perform the income-stabilizing role, they may also have unintended impacts on farmers’ behavior, which could in turn significantly influence the resilience of the whole agricultural sector. Based on the literature review, it can be argued that DP have a direct impact on resilience (by increasing farmers income and guaranteeing stability of this share of income) as well as significant indirect repercussions by influencing system features and behavior that affect resilience (Figure 2).

Results and Discussion.

Starting at the macro level, DP first of all negatively impact (increase) input and land (rental) prices. There is an extensive body of literature on this topic (Kirwan & Roberts, 2016; Severini *et al.*, 2016; Graubner, 2018). Empirical evidence suggests partial incidence of up to 50 percent and more, i.e. subsidies up to half

of their value are reflected in land prices (Latruffe & Le Mouél, 2009).

DP, guaranteeing stable incomes, as well as additional payments specifically for young farmers (in many EU states), contributes to attracting them to agricultural business as well as to keeping them in it (Volkov *et al.*, 2019; May *et al.*, 2019). The system with a population with a relatively higher share of younger age individuals is usually indicated as more resilient, since younger people are usually more flexible, mobile and have more abilities to adapt to changing conditions (Martin *et al.*, 2016).

The largest influence of DP on resilience is, however, made through the micro level, since these payments are paid directly to farmers, impacting their income, attitudes and behavior. A great share of research dedicated to DP’s impact on behavior is associated with risk management (Marchall *et al.*, 2012; Boto & Pandya-Lorch, 2013; Linkov *et al.*, 2014). Many researchers have studied the relationship between DP and insurance adoption and have concluded that payments do influence farmers’ decisions not to adopt crop/animal insurance: Chakir & Hardelin (2014) have shown that subsidies negatively affected insurance demand in rapeseed production in France, and Finger & Lehmann’s (2012) study results indicate that the larger the share of direct payments for total farm revenue, the less attractive are insurances as risk management strategy for farmers. This can be due to several reasons: first, the stability of incomes has an insurance effect in themselves, and

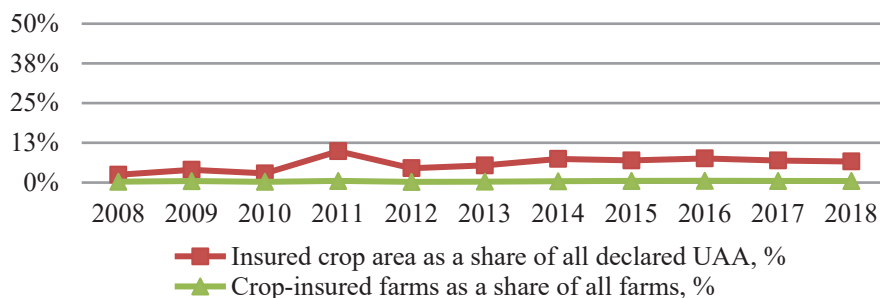


Figure 3. A share of insured crop area and a share of farms holding crop insurance in the period 2008–2018 in Lithuania.

Source: based on data obtained from the Ministry of Agriculture of the Republic of Lithuania.

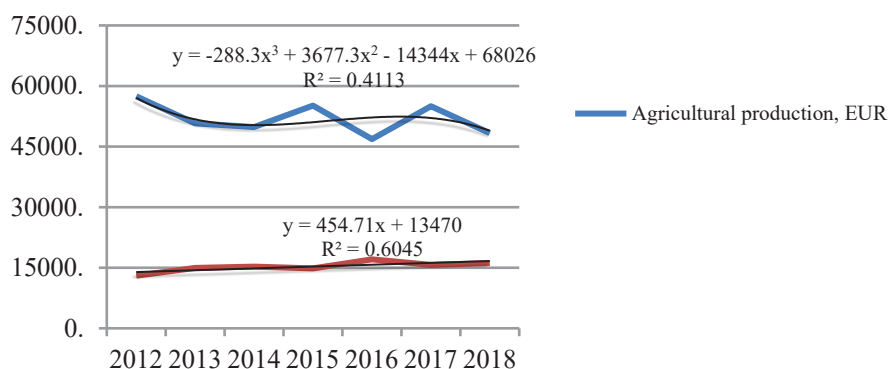


Figure 4. Average agricultural production and subsidies (direct payments, LFA and ecological farming) of an average Lithuanian farm in the period 2012–2018.

Source: compiled by author, based on FADN data.

second, DP income might increase farmers' wealth, and if farmers are risk-averse, they are expected to decrease their level of risk aversion, thus decreasing farmers' demand for insurances (Kimura *et al.*, 2010; Finger & Lehmann, 2012). These reasons can explain why the uptake of insurance is so low in the majority of EU states. Lithuania is not an exception. Although the conditions for taking up insurance here are very favorable (the state has been subsidizing up to 65% of insurance premiums for a number of years), the uptake of insurance is very low – more than 95% of farmers do not insure their risks (Figure 3).

The other potential way how the DP influence farmers' risk management behavior is by changing their production decisions. Capitano *et al.* (2014) notes that DP, on the one hand, can encourage farmers to invest and increase his production capacity, however, on the other hand, farmers can use this additional money as a substitute to his activity, decreasing their agricultural production. That may be the case in Lithuania, where agricultural production (crop and animal) is decreasing while subsidies are increasing (Figure 4).

DP, even decoupled, could continue influencing farmers' decisions on the production structure,

encouraging them to grow/produce the sorts of production that was (or still is) coupled with DP instead of growing/producing the sorts most required by the market and potentially more profitable (Breen *et al.*, 2005). It is also argued, that DP have an impact on the level of diversification on the farm (Mishra *et al.*, 2004; Maye *et al.*, 2009), which in turn significantly influences farm's resilience.

These examples together with other possible DP impacts on behavior show that DP influence on resilience is multidimensional and in many cases involve behavior (and attitude) change. In order to get a deeper view on the possible DP influence on behavior of Lithuanian farmers, an extensive survey is being carried out. Preliminary results should be available at the time of the conference. Results from the survey, as well as the statistical data, will be used to analyze the impact of DP on Lithuanian agricultural sector.

Conclusions

1. The future sustainability of agriculture will increasingly depend on its resilience – capacity to withstand various perturbations and recover from them. In order to increase resilience of this sector,

- it is necessary to know what factors (conditions) help boost it, and what hinder its development. However, studies of economic resilience in agriculture are scarce, fragmented and mainly focused on ecological rather than economical side of the system.
2. In order to fill this gap, an extensive literature review was performed and a summarized list of factors that are mentioned as potentially influencing resilience prepared. These factors were classified under two broad groups: system features and behavioral patterns. The analysis of the literature shows that most important behavioral patterns contributing to increasing resilience are learning, innovation, collaboration and risk management.
 3. EU direct payments are the most financed EU support scheme for agriculture; however, research on its impact on the resilience of the sector is especially limited. In this paper, it is argued that these payments have a direct as well as a strong indirect impact on resilience. This impact is transferred mostly through changing farms' financial capabilities as well as farmers' attitudes and behaviors, and is argued to be both positive and negative. Such phenomena as low crop insurance uptake and decrease in productivity may be due to the overcrowding effects of direct payments. These hypotheses are being tested in the survey which is being conducted in the meantime.

References

- Almås, R., & Campbell, H. (2012). Introduction. *Rethinking Agricultural Policy Regimes Research in Rural Sociology and Development*, 1–22. DOI: 10.1108/s1057-1922(2012)0000018003.
- Altieri, M.A., & Nicholls, C.I. (2017). The adaptation and mitigation potential of traditional agriculture in a changing climate. *Climatic Change*, 140 (1), 33–45.
- Angeon, V., & Bates, S. (2014). Reviewing Composite Vulnerability and Resilience Indexes: A Sustainable Approach and Application. *SSRN Electronic Journal*. DOI: 10.2139/ssrn.2437980.
- Angulo, A.M., Mur, J., & Trivez, F.J. (2017). Measuring resilience to economic shocks: an application to Spain. *The Annals of Regional Science*, 60(2), 349–373. DOI: 10.1007/s00168-017-0815-8.
- Biggs, R., Schlüter, M., Biggs, D., Bohensky, E.L., BurnSilver, S., Cundill, G., ... West, P.C. (2012). Toward principles for enhancing the resilience of ecosystem services. *Annual Review of Environment and Resources*, 37, 421–448.
- Boschma, R. (2015). Towards an Evolutionary Perspective on Regional Resilience. *Regional Studies*, 49(5), 733–751. DOI: 10.1080/00343404.2014.959481.
- Boto, I., & Pandya-Lorch, R. (2013). Agricultural resilience in the face of crisis and shocks. Brussels Rural Development Briefings. Retrieved February 19, 2020, from https://brusselsbriefings.files.wordpress.com/2009/02/cta-reader-30_agricultural-resilience-eng-rev-2.pdf.
- Breen, J.P., Hennessy, T.C., & Thorne, F.S. (2005). The effect of decoupling on the decision to produce: An Irish case study. *Food Policy*, 30(2), 129–144. DOI: 10.1016/j.foodpol.2005.03.001.
- Bristow, G., & Healy, A. (2013). Regional Resilience: An Agency Perspective. *Regional Studies*, 48(5), 923–935. DOI: 10.1080/00343404.2013.854879.
- Bristow, G., & Healy, A. (2017). Innovation and regional economic resilience: an exploratory analysis. *The Annals of Regional Science*, 60(2), 265–284. DOI: 10.1007/s00168-017-0841-6.
- Cabell, J.F., & Oelofse, M. (2012). An Indicator Framework for Assessing Agroecosystem Resilience. *Ecology and Society*, 17(1), DOI: 10.5751/es-04666-170118.
- Capitanio, F., Adinolfi, F., Enjolras, G., & Aubert, M. (2014). Direct payments, crop insurance and the volatility of farm income: some evidence in France and in Italy. *New Medit*, 13(1), 31–40.
- Chakir, R., & Hardelin, J. (2014). Crop Insurance and pesticide use in French agriculture: an empirical analysis. *Revue d'Études En Agriculture Et Environnement*, 95(01), 25–50. DOI: 10.4074/s1966960714011035.
- Darnhofer, I., Bellon, S., Dedieu, B., & Milestad, R. (2011). Adaptiveness to Enhance the Sustainability of Farming Systems. *Sustainable Agriculture Vol. 2*, 45–58. DOI: 10.1007/978-94-007-0394-0_4.
- Davies, A., & Tonts, M. (2009). Economic Diversity and Regional Socioeconomic Performance: An Empirical Analysis of the Western Australian Grain Belt. *Geographical Research*, 48(3), 223–234.
- Doran, J., & Fingleton, B. (2017). US Metropolitan Area Resilience: Insights from dynamic spatial panel estimation. *Environment and Planning A: Economy and Space*, 50(1), 111–132. DOI: 10.1177/0308518x17736067.
- Evans, R., & Karecha, J. (2013). Staying on Top: Why is Munich so Resilient and Successful? *European Planning Studies*, 22(6), 1259–1279. DOI: 10.1080/09654313.2013.778958.
- Fagiolo, G. (2016). Macroeconomic Policy in DSGE and Agent-Based Models Redux: New Developments and Challenges Ahead. *SSRN Electronic Journal*. DOI: 10.2139/ssrn.2763735.

- Finger, R., & Lehmann, N. (2012). The influence of direct payments on farmers' hail insurance decisions. *Agricultural Economics*, 43(3), 343–354. DOI: 10.1111/j.1574-0862.2012.00587.x.
- Fingleton, B., Garretsen, H., & Martin, R. (2012). Recessionary Shocks and Regional Employment: Evidence on the Resilience of U.K. Regions. *Journal of Regional Science*, 52(1), 109–133. DOI: 10.1111/j.1467-9787.2011.00755.x.
- Graubner, M. (2017). Lost in space? The effect of direct payments on land rental prices. *European Review of Agricultural Economics*, 45(2), 143–171. DOI: 10.1093/erae/jbx027.
- Kimura, S., Antón, J., & LeThi, C. (2010). Farm Level Analysis of Risk and Risk Management Strategies and Policies. *OECD Food, Agriculture and Fisheries Papers*. DOI: 10.1787/5kmd6b5rl5kd-en.
- Kirwan, B.E., & Roberts, M.J. (2016). Who Really Benefits from Agricultural Subsidies? Evidence from Field-level Data. *American Journal of Agricultural Economics*, 98(4), 1095–1113. DOI: 10.1093/ajae/aaw022.
- Latruffe, L., & Mouël, C.L. (2009). Capitalization Of Government Support In Agricultural Land Prices: What Do We Know? *Journal of Economic Surveys*, 23(4), 659–691. DOI: 10.1111/j.1467-6419.2009.00575.
- Linkov, I., Bridges, T., Creutzig, F., Decker, J., Fox-Lent, C., Kröger, ... Thiel-Clemen, T. (2014). Changing the resilience paradigm. *Nature Climate Change*, 4, 407–409.
- Martin, R., & Sunley, P. (2015). On the notion of regional economic resilience: conceptualization and explanation. *Journal of Economic Geography*, 15(1), 1–42. DOI: 10.1093/jeg/lbu015.
- Martin, R., Sunley, P., Gardiner, B., & Tyler, P. (2016). How Regions React to Recessions: Resilience and the Role of Economic Structure. *Regional Studies*, 50(4), 561–585. DOI: 10.1080/00343404.2015.1136410.
- May, D., Arancibia, S., Behrendt, K., & Adams, J. (2019). Preventing young farmers from leaving the farm: Investigating the effectiveness of the young farmer payment using a behavioural approach. *Land Use Policy*, 82, 317–327.
- Maye, D., Ilbery, B., & Watts, D. (2009). Farm diversification, tenancy and CAP reform: Results from a survey of tenant farmers in England. *Journal of Rural Studies*, 25(3), 333–342. DOI: 10.1016/j.jrurstud.2009.03.003.
- Mishra, A.K., El-Osta, H.S., & Sandretto, C.L. (2004). Factors affecting farm enterprise diversification. *Agricultural Finance Review*, 64(2), 151–166. DOI: 10.1108/00214660480001160.
- Morkūnas, M., Volkov, A., & Pazienza, P. (2018). How Resistant is the Agricultural Sector? Economic Resilience Exploited. *Economics & Sociology*, 11(3), 321–332. DOI: 10.14254/2071-789x.2018/11-3/19.
- Obschonka, M., Stuetzer, M., Audretsch, D.B., Rentfrow, P.J., Potter, J., & Gosling, S.D. (2015). Macropsychological Factors Predict Regional Economic Resilience During a Major Economic Crisis. *Social Psychological and Personality Science*, 7(2), 95–104. DOI: 10.1177/1948550615608402.
- Sabatino, M. (2019). Economic resilience and social capital of the Italian region. *International Review of Economics & Finance*, 61, 355–367. DOI: 10.1016/j.iref.2019.02.011.
- Sawicka, B. (2019). Resilient Agricultural Practices. *Handbook of the Historiography of Biology Historiographies of Science*, 1–13. DOI: 10.1007/978-3-319-69626-3_42-1.
- Sellberg, M., Ryan, P., Borgström, S., Norström, A., & Peterson, G. (2018). From resilience thinking to Resilience Planning: Lessons from practice. *Journal of Environmental Management*, 217, 906–918. DOI: 10.1016/j.jenvman.2018.04.012.
- Severini, S., Tantari, A., & Tommaso, G.D. (2016). Do CAP direct payments stabilise farm income? Empirical evidences from a constant sample of Italian farms. *Agricultural and Food Economics*, 4(1), DOI: 10.1186/s40100-016-0050-0.
- Volkov, A., Balezentis, T., Morkunas, M., & Streimikiene, D. (2019). Who Benefits from CAP? The Way the Direct Payments System Impacts Socioeconomic Sustainability of Small Farms. *Sustainability*, 11(7), 2112. DOI: 10.3390/su11072112.
- Wink, R., Kirchner, L., Koch, F., & Speda, D. (2018). The economic resilience of Stuttgart: vulnerable but resilient and adaptable. *Economic Crisis and the Resilience of Regions*, 41–60. DOI: 10.4337/9781785364006.00008.
- Wolman, H., Wial, H., Clair, T.S., & Hill, E. (2017). Shocks and Regional Economic Resilience. *Coping with Adversity*. DOI: 10.7591/cornell/9780801451690.003.0002.

CHALLENGES IN HUMAN RESOURCE MANAGEMENT IN THE CULTURE INDUSTRY IN LATVIA

***Sanita Bethere, Lasma Licite-Kurbe**

Latvia University of Life Sciences and Technologies, Latvia

*Corresponding author's email: sanita.bethere@gmail.com

Abstract

The culture industry and its human resources have been little researched in Latvia, yet research on the culture industry is important, because the industry makes a significant contribution to economic growth by promoting employment and the development of competitive regions. The culture industry encompasses libraries, folk art, theatre, music, museums, the creative industry and other sub-industries, yet in recent years those working in all the culture sub-industries faced various challenges, including: a low remuneration and insufficient monetary and non-monetary bonuses, resulting in lower job satisfaction and a high personnel turnover. Accordingly, the aim of the research is to develop recommendations for hiring and retaining human resources by examining challenges in managing human resources in the culture industry. The authors conducted a survey among the personnel of the Board of Culture of Jelgava municipality. The survey found that the main challenges faced by the administration of the Board of Culture were an uncompetitive remuneration, the aging of the personnel and generational change as well as inefficient and insufficient motivation for working. The research has developed two scenarios for recruiting: 'promotion of creativity and non-monetary motivation' that aim to publicly appreciate human resources, so that they would feel important and significant as well as facilitate creativity, innovation and collective solidarity, while for the purpose of retaining human resources in a long-term and decreasing their turnover, the second scenario 'competitive remuneration and the differentiation by position category' aims to gradually raise the remuneration and differentiate it for all categories of personnel.

Key words: culture industry, human resources, motivation.

Introduction

The culture industry is one of the fastest growing industries, and the value added of the culture industry is almost more than 10% of GDP in developed countries (Shu-sheng, 2012). However, the culture industry and its contribution to the national economy has been relatively little researched; besides, the scope of the research has been narrow. Compared with other industries of the national economy of Latvia, only indirect attention has been paid to it. Nevertheless, research on the culture industry is important, as it is not only a consuming industry – the industry considerably contributes to economic growth (Yusof *et al.*, 2013; Bandelj & Morgan, 2015; Greffe, 2016), thereby increasing employment (Marcen, 2014; Schaufeli, 2018; Bryan *et al.*, 2000), the development of innovative products (Yusof *et al.*, 2013), development of R&D investment (Varsakelis, 2001) as well as the development of competitive regions (Bille & Schulze, 2006). In addition, culture plays an important role in performing various social functions – the culture forms the system of individual and societal values, knowledge and skills, experience (Santoso & Schrepp, 2019), promotes local community development and identity formation (Ministry of Culture, 2014), as the culture industry is broad in scope, encompassing libraries, folk art, theatre, music, museums, the creative industry and other sub-industries. Not only an individual's personality and life quality but also the growth of the society, regions and the country depend on the diversity, richness and accessibility of the cultural environment and the participation of

active and creative individuals in the development of it (Ministry of Culture, 2014). Through art, it is possible to express the moods of society and create common values. Culture is the only source of human values (Rifkins, 2004).

Although scientific research has emphasized the importance of culture in the development of any country and nation, the culture industry in Latvia faces various challenges that have a significant impact on the development of human resources in this industry. The Cultural Policy Guidelines 2014–2020 'Creative Latvia' identified several challenges in the culture industry, incl. – no targeted research and economic effect assessment of the creative industries sector and a lack of funding for the sphere of culture. As a result of the economic crisis, funding for culture has been significantly reduced, which has affected support for the creative process. Although there are opportunities to diversify sources of finance, given the small market and limited financial capacity of the population, there is still a need for government support for preserving cultural capital and providing cultural institutions with a basis for developing new initiatives to maintain the national identity and value in the society. It should also be taken in consideration that access to finance and support for the culture industry as a whole have a significant effect on the availability and development of human resources in the culture industry.

The present research therefore aims to develop recommendations for hiring and retaining human resources by examining challenges in managing human resources in the culture industry. To achieve

the aim, the following specific research tasks have been set: 1) describe challenges in managing human resources in the culture industry; 2) develop scenarios for recruiting and retaining human resources for the Board of Culture of Jelgava municipality.

Materials and Methods

To analyse trends in the culture industry in Latvia in the context of human resources, statistical analysis was employed, while a survey and interviews with three experts of the culture industry were used to identify challenges in human resource management in the culture industry. The target population was the personnel of the Board of Culture of Jelgava municipality aged 19–86 (133 employees). The Board of Culture was selected as the research object because in 2019 its 133 personnel worked in 14 cultural centres, 22 public libraries and 98 folk art and craft or amateur groups, thereby representing the human resources of various fields of culture, as well as it is a regional institution, which at the same time reveal challenges in the regions of Latvia in terms of human resources in the culture industry. The total number of respondents was 107, which means that totally 80% of the personnel of the Board of Culture completed their questionnaires. Given the diversity of the culture industry, the survey examined the human resources of the culture industry in the context of three personnel categories: creative personnel (leaders of amateur art groups, concertmasters, choir masters and other specialists, genre leaders, sound and light operators), cultural personnel (administrators, cultural supervisors

and event organizers) and library personnel (library heads, librarians and a local history specialist). The research used the scenario method to determine the ways of recruitment and long-term retention of human resources for the Board of Culture.

The research analysed research papers of international scientific journals on the role of culture, research studies conducted by the Ministry of Culture, data of the Central Statistical Bureau, internal and external legal documents of the local government of Jelgava municipality and the legal framework of the Republic of Latvia.

Results and Discussion

Challenges in human resource management in the culture industry. The analysis of the survey data on motivational factors for human resources (Figure 1) allows concluding that the most important factor (57% of the respondents indicated it as the first priority) was an interesting, creative and meaningful job, while a competitive remuneration was mentioned as the second most important factor (16% of the respondents mentioned it as the first priority). The professionals of all the backgrounds – creative, cultural and library – agreed with the role that was played by meaningful work.

The cultural experts interviewed also point out that a competitive remuneration was one of the most important motivational factors; however, it should be taken into consideration that ‘the attitude towards work is encoded in a man and not in a competitive remuneration, and high salaries combined with poor

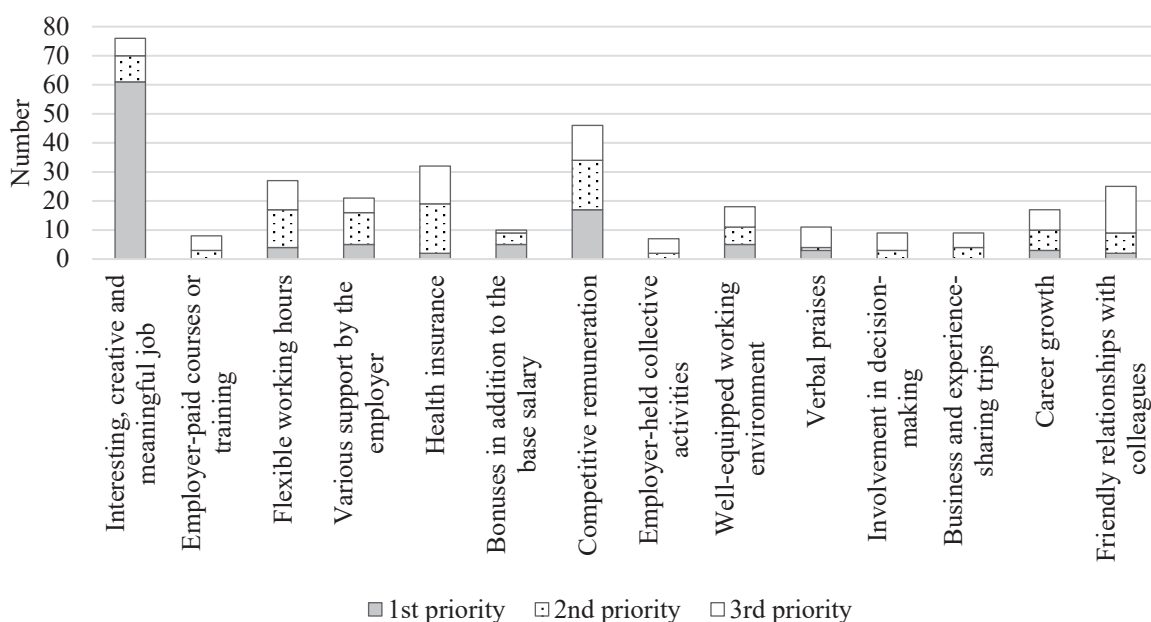


Figure 1. Distribution of motivational factors for the human resources of the Board of Culture by priority.

Source: authors’ construction based on the survey of personnel of the Board of Culture of Jelgava municipality, 2019 (n=107).

Table 1

Average monthly gross salaries of employees in municipal institutions in Latvia and Jelgava municipality by kind of activity in the period 2015–2018, EUR

Kind of activity	2015	2016	2017	2018	2018/2015, %
Latvia					
Art, entertainment and recreation	586	617	660	712	21.5
Creative, artistic and entertainment activities	589	621	669	720	22.2
Libraries, museums and activities of other cultural institutions	576	604	639	689	19.6
Jelgava municipality					
Libraries	531	523	538	571	7.5
Creative personnel (amateur art groups)	704	699	694	725	3.0
Cultural institutions	554	583	618	689	24.3

Source: authors' own compilation based on data of the Central Statistical Bureau and documents of the Personnel Department of Jelgava municipality, 2015–2018.

management will only be motivational in a short-term'. Nevertheless, the experts overall acknowledged that one of the most important problems in the culture industry was the low remuneration. As a result of the economic crisis, funding for the culture industry, including salaries for those working in the culture industry, was considerably reduced, which increased the risk of losing professional specialists in the labour market as well as a high employee turnover in organizations, especially in the regions of Latvia (Table 1).

As shown in Table 1, the average monthly gross salary in the field of art, entertainment and recreation in municipal institutions was EUR 712 in 2018, and compared with 2015, it rose by 21.5%. In Jelgava municipality, the average monthly gross salary in the same field totalled EUR 662 in 2018; compared with the national average, it was 7% lower. In 2018 in Jelgava municipality, the lowest average monthly gross salary in the culture industry was reported for librarians, at EUR 571. In the period 2015-2018, the average monthly gross salary of creative personnel varied, which could be explained by the changing numbers of amateur art groups and their leaders.

The survey found that the available monetary and non-monetary bonuses are taken for granted, being not motivational, by employees, and are consequently underestimated.

In accordance with the Law on Remuneration of Officials and Employees of State and Local Government Authorities, the following monetary and non-monetary bonuses are available for the human resources of the Board of Culture of Jelgava municipality: social security, a steady and regular remuneration, paid health insurance policies, a compulsory health check every three years, a bonus of up to 20% of the basic monthly salary if the employee, in addition to the direct duties, replaces a personnel

member being absent or takes an unfilled vacancy or performs other duties, as well as various benefits. In addition to the mandatory additional leave provided for by the Labour Law, the employee is granted one to three working day additional leave if the employee cares for one or more children under the age of 16 or a disabled child under the age of 18, as well as paid holidays (one holiday on the first day of school due to commencement of the child's schooling in years 1–4, not more than three holidays due to marriage and one holiday on the graduation day when the employee or his/her child graduates from an educational institution) as well as training leave with the pay for the time of the leave. However, the respondents emphasized the importance of non-monetary motivational factors – an opportunity to get regular feedback and praises for well-done work. The results of the survey also showed that the employees preferred a democratic management style and a friendly atmosphere in the team. This was also confirmed by the experts that 'it is very important for the manager to know what the employees think, make to some extent a joint decision and seek to decide collectively, thereby promoting the collective responsibility for the work and ongoing processes'.

An important challenge faced by the Board of Culture in the context of human resources is personnel ageing and generational change. The personnel of the Board of Culture of Jelgava municipality are represented by four generations. The most personnel were aged 55–74 (54 personnel) and 38 were aged less than 54 (52). There were 23 younger employees (aged 19–37). The longest employment relationship was 38 years. One can conclude that there is a risk of failure to replace the human resources in the coming years. Library personnel in particular could be most significantly affected by the replacement of the personnel, as part of them were of pre-retirement

or retirement age. Besides, younger personnel tend to leave the Board of Culture more often than others because of a low remuneration and often because of the specifics of the culture industry, e.g. being a cultural employee often involves working in evenings and on weekends. As a result, if employees do not receive a competitive and motivational remuneration, they more often decide to change their jobs. Furthermore, there is also a lack of qualified specialists among creative personnel. Creative personnel work part-time, resulting in a low and non-motivational remuneration. Twenty five creative personnel took several part-time positions (were leaders of several amateur art groups), which could be explained by a lack of qualified specialists in the vicinity of Jelgava municipality and Jelgava city. However, to attract qualified specialists, a competitive remuneration has to be paid because no employee wants long-term employment based on enthusiasm and for a low remuneration.

In view of the fact that the challenges identified in human resource management related to employee motivation, the research developed two scenarios for recruiting and retaining human resources for the Board of Culture, taking into account the problems identified.

Scenarios for recruiting and retaining human resources in the culture industry. Scenario 1: Promotion of creativity and non-monetary motivation. In the interview, one of the cultural experts states that one of the employer's challenges is to ensure that 'the employee does not lose motivation to perform the job duties at high quality and productivity, as well as grow and develop professionally. Therefore, efforts have to be made to develop the willingness of employees to work with creativity'. This was also confirmed by another expert interviewed who stressed the importance of working on raising employee self-esteem. The results of the survey also showed that it was important for the employees to feel important and valued as well as receive regular feedback and verbal praises for well-done work.

Since the survey revealed that praises and appreciation were important to the employees (44% of the respondents said they would appreciate public praises and appreciation for their work), the authors suggest introducing a thank you event once a year, which honours the employees who have achieved high performance during the year. It would be an opportunity to give verbal praises and give thanks (which is an important form of appreciation for some employees). This kind of event would allow employees to feel their significance.

To encourage creative inspiration and enthusiasm among employees, it is suggested to organize summer or winter creative camps to unleash creativity in them. This is a way how to unite groups of employees,

promote a positive atmosphere among the colleagues and develop mutual cooperation, so that the employees feel united. According to the survey, 77% of the respondents supported employer-held non-work activities, excursions and other collective activities.

To unleash creativity and satisfy the aspirations of cultural personnel for achievements, the authors suggest holding a scenario development and implementation competition that would serve as one of the motivational factors, as it enables the employees to prove themselves as well as unleashes creativity in them. This is important because 86% of the respondents said that achievements were important to them. For the administration, however, this is essential because it allows assessing the creativity of employees and the quality of events held in cultural centres. The competition would award a cash prize for three cultural supervisors whose scenarios written and their implementation in a particular event have been appreciated the most.

A good way to motivate and assess personnel and broaden their views is to reimburse their expenses on experience-sharing trips abroad. This is one of the motivational factors that attract younger employees, as well as a good way to motivate and appreciate the employees who make a significant personal contribution to their job responsibilities. An opportunity for going abroad for sharing experience could be given to two employees based on their performance evaluation for a reporting period.

Scenario 2: Competitive remuneration and the differentiation by position category. The results of the survey confirmed that the employees were motivated by meaningful, interesting and creative work and a competitive remuneration. Although various monetary and non-monetary bonuses are available to the personnel of the Board of Culture of Jelgava municipality, which partly offset the low and uncompetitive remuneration, it has to be taken in account that the bonuses alone are not enough. It is important to emphasize that all the personnel are currently eligible for a remuneration adjustment based on the job classification, thereby providing equal pay for equal work. Based on the survey conducted and available information on personnel remuneration, it is necessary to develop a competitive remuneration system for each category of job positions.

Creative personnel – leaders of amateur art groups in each genre receive equal pay in accordance with the job category established. However, the remuneration differentiation according to the results achieved in shows, the amateur art category and overall performance is necessary. At present, creative personnel are not included in the common evaluation system of the local government of Jelgava municipality, as it is not correct to evaluate the performance of

creative personnel according to the same principles as 'standard' full-time employees. The specifics of work done by creative personnel and the achievable results against which they could be evaluated are different. Therefore, it is necessary to develop a set of rules for the remuneration of amateur art groups and creative personnel, which includes the principles ensuring the traceability of remuneration components and calculations as well as a consistent approach to setting remuneration. Once a year, it would be necessary to perform an evaluation of the performance of an amateur art group and its leader, which would involve identifying the category of the amateur art group and evaluating the individual contribution of the amateur art group's leader. In accordance with the set of rules established, the remuneration of an amateur art group would consist of the basic rate and the variable rate (fixed or variable bonuses of up to 20% of the monthly salary for the position, depending on participation in activities of various levels and types (shows, competitions, festivals etc.) and other bonuses (if any)).

The amount of remuneration has to be set in order to be commensurate with the remuneration for equal work. Totally, the set of rules defines three remuneration categories: Category 1 for choirs, dance ensembles and orchestras; Category 2 for folklore and folk music groups, vocal ensembles, amateur theatres, folk applied art groups; Category 3 for world-level contemporary dance groups, pop bands, theatre sport groups and other non-folk art groups. Each category is subdivided into three employee categories and four amateur art group categories. The categorization of employees and amateur art groups is done according to performance evaluation results. The basic salary rate is determined based on the categories of personnel and amateur art groups, to which, according to performance evaluation results, a variable rate not exceeding 20% of the monthly salary rate is applied. The set of rules governing the activities of amateur art groups and setting remuneration for creative personnel could serve as a powerful motivational tool to motivate, hire and retain creative personnel not only in the institution researched but also in other similar organizations.

The cultural personnel are also paid the same salary for performing the same duties. An analysis of the contributions of cultural supervisors and event organizers in respect to their duties performed allows concluding that their contributions differ significantly. Accordingly, it is necessary to consider the possibilities of differentiating the remuneration of this personnel. By taking into consideration the occupancy of cultural centres, the number and variety of events organized by cultural directors, as well as the number of amateur art groups operating in a particular rural community

centre, it is necessary to differentiate the remuneration of cultural personnel into three categories:

- Category 1 – a lot of events and activities are held at cultural centres, a large number of events are organized and a variety of activities are offered to residents; the number of amateur art groups is from 7 to 12;
- Category 2 – a medium number of activities are held at cultural centres, a medium number of events are organized and the range of events is not increased (mostly uniform events that are repeated every year); the number of amateur art groups is from 5 to 7;
- Category 3 – a relatively small number of activities are held at cultural centres, a small number of events are organized; the number of amateur art groups is less than 5.

It is important to evaluate an employee's performance and personal contribution as well as effectiveness. Remuneration differentiation is one way how to evaluate each employee. It should be understood that the categorization of cultural personnel also helps to determine the amount of work involved. Besides, it is important to evaluate the individual contribution to the event, whether the cultural supervisor creates scenarios for an event and conducts it himself or herself, or outsourcing opportunities saving the supervisor's personal time are used. The categorization of cultural personnel would need to be reviewed once a year according to the work done during the reporting period and the number of amateur art groups operating in the cultural centre. Taking into account the current remuneration of cultural personnel, which is, on average, EUR 689 and the basic monthly salary for 2020 estimated at EUR 976.46, the authors of the present research believe that the average monthly salary of cultural personnel in 2020 should reach at least EUR 892, and it is necessary to increase it to a competitive level.

The remuneration of library personnel is uncompetitive, which could create a major challenge to attracting new and qualified professionals in the future. The most aged personnel are found among the library personnel in particular; consequently, several personnel members are expected to retire soon. At present, the library personnel is divided into three categories, and a monthly salary is set for each category. To date, the library personnel have been categorized according to the number of registered readers in the library:

- Category 1 includes the largest rural libraries in terms of number of registered readers – over 401 registered readers;
- Category 2 includes rural libraries with a number of registered readers from 201 to 400;
- Category 3 includes rural libraries with a number of registered readers less than 200.

Table 2

**Scenarios for recruiting and retaining human resources for the Board of
Culture of Jelgava municipality**

Scenario	Problems identified	Solutions	Brief description	Expected cost a year, EUR
Scenario 1: <i>Promotion of creativity and non-monetary motivation</i>	Need for personnel to feel important and significant; Lack of public praises	Thank you event	Implemented once a year to honour employees for their outstanding merits	~ 2000 EUR
	Lack of creativity and innovation	Creative camps	Implemented once a year to contribute to innovation and team consolidation	~ 2000 EUR
	Lack of innovation and routine	Event scenario development and implementation competition	Implemented once a year to contribute to creativity and the quality of events	Money prizes: 1 st place – EUR 200 2 nd place – EUR 150 3 rd place – EUR 100
	Lack of motivational bonuses	Experience-sharing trips abroad	Implemented once a year to broaden one's horizons and get inspiration	From EUR 200 to EUR 2000
Scenario 2: <i>Competitive remuneration and the differentiation by position category</i>	Low and uncompetitive remuneration Equal remuneration system is applied	Remuneration system for creative personnel	A set of rules for the remuneration of amateur art groups and creative personnel that differentiate the remuneration according to the personal contribution of the employee and the category of the amateur art group	Calculations are still in process
		Remuneration system for cultural personnel	Higher remuneration and the differentiation into three categories	Total funding needed for raising and differentiating the remuneration EUR 100 000
		Remuneration system for library personnel		

Source: authors' own compilation.

After assessing the performance of rural libraries and librarians and the librarians' personal contribution to the development and improvement of the libraries' performance, it is required improving the current system, leaving Category 1 unchanged. A large number of registered readers means more work and, after an increase in the number of registered readers, the personal contribution and performance of library personnel has to be assessed. Category 2 has to include the libraries and their personnel who, in addition to providing basic library functions and services, take part in various projects, which involves engaging various audiences in the projects and sometimes working outside normal office hours. Category 3, however, has to include all the libraries and their librarians who provide only the basic library functions and services and do not contribute to the involvement of local residents in the activities of the libraries through organizing various events and activities.

Establishing categories for library personnel would increase motivation and appreciation for those

who already put a lot of efforts into their libraries, yet in those who are not active enough in this respect, a higher remuneration would arouse a wish to make their libraries perform better. Taking into account the current remuneration of library personnel, which is, on average, EUR 571 and the basic monthly salary for 2020 estimated at EUR 976.46, the authors believe that the average monthly salary of library personnel in 2020 should reach at least EUR 758, and it is necessary to continue increasing it to a competitive level. Both scenarios are summarised in Table 2.

As shown in Table 2, the largest investment is needed for Scenario 2, as the total expense exceeds EUR 100 000. Introducing Scenario 1 requires an investment in the range of EUR 4650-6650 within a calendar year. Of course, it is more cost-efficient to implement Scenario 1, yet in general long-term solutions would be needed, which in this case would be an increase in remuneration and the differentiation of remuneration. Overall, the authors recommend implementing both scenarios to the extent possible,

as they are complementary: Scenario 1 would help to engage and motivate well-performing employees on a day-to-day basis, while Scenario 2 would promote personnel retention in a long-term.

Overall, one could conclude that the monetary and non-monetary bonuses introduced by the Board of Culture of Jelgava municipality are often taken for granted and not sufficiently appreciated by the employees. It is quite difficult to vary motivational tools because the Board of Culture is governed by the Law on Local Governments and the Law on Remuneration of Officials and Employees of State and Local Government Authorities. However, this does not exclude a possibility for the administration of the Board of Culture to seek solutions in order to supplement non-monetary bonuses with significant work experience-sharing trips within Latvia or abroad. Such trips not only broaden the personnel's horizons but also help the personnel to appreciate their work environment and the bonuses available to them.

Conclusions

1. In accordance with the national legal framework and internal legal documents of the organization, various monetary and non-monetary bonuses are available for the human resources of the Board of Culture of Jelgava municipality: social security, a steady and regular remuneration, paid health insurance policies, various benefits and additional leave. However, the mentioned bonuses are taken for granted and not sufficiently appreciated by the employees. Besides, the employees surveyed indicated the need for non-monetary bonuses – praises and appreciation. Accordingly,

it is necessary to increase employees' motivation by introducing non-monetary bonuses – work experience-sharing trips within Latvia or abroad and a thank you event – which would raise their feeling of appreciation for their work, as well as holding creative camps for them.

2. One of the most important problems faced by culture industry employees in Latvia is a low remuneration. For this reason, the Board of Culture of Jelgava municipality needs to review the remuneration policy for cultural and library personnel, as the remuneration for any personnel category is currently uncompetitive. In order for personnel to be evaluated in terms of their personal contribution and performance, in every team cultural and library personnel have to be differentiated into three categories, which to the extent possible would allow differentiating monthly salaries based on the criteria set for each category. For creative personnel, however, it is important to introduce an evaluation system that objectively takes into account a personal contribution of the leader of an amateur art group and their collective achievements, thereby differentiating their monthly salaries and setting variable bonuses for their performance.
3. The Board of Culture of Jelgava municipality also faces the problem of ageing of its personnel; therefore, considerable personnel replacement is expected in the future, especially among its library personnel. To solve this problem, it is necessary to set criteria for a competitive remuneration and enhance the motivation system to attract new highly-qualified specialists.

References

- Bandelj, N., & Morgan, P.J. (2015). Culture and Economy. In J.D. Wright (Ed.), *International Encyclopedia of the Social & Behavioral Sciences* (pp. 535–541). Elsevier Ltd.
- Bille, T., & Schulze, G.G. (2006). Culture in Urban and Regional Development. In V.A. Ginsburgh & D. Throsby (Eds.), *Handbook of the Economics of Art and Culture* (pp. 1051–1099). North Holland.
- Bryan, J., Hill, S., Munday, M., & Roberts, A. (2000). Assessing the role of the arts and cultural industries in a local economy. *Environment and Planning*, 32, 1391–1408. DOI: 10.1068/a32168.
- Grefe, X. (2016). From culture to creativity and the creative economy: A new agenda for cultural economics. *City, Culture and Society*, 7 (2), 71–74. DOI: 10.1016/j.ccs.2015.12.008.
- Ministry of Culture. (2014). *Kultūrpolitikas pamatnostādnes 2014.–2020.gadam 'Radošā Latvija'* (Cultural Policy Guidelines 2014–2020 'Creative Latvia'). Riga. Retrieved December 30, 2019, from https://www.km.gov.lv/uploads/ckeditor/files/KM_dokumenti/Radosa_Latvija.pdf. (in Latvian).
- Marcen, M. (2014). The role of culture on self-employment. *Economic Modelling*, 44 (1), S20–S32. DOI: 10.1016/j.econmod.2013.12.008.
- Rifkins, Dž. (2004). *Jaunās ekonomikas laikmets* (New Economic Era). Riga: Jumava. (in Latvian).
- Santoso, H.B., & Schrepp, M. (2019). The impact of culture and product on the subjective importance of user experience aspects. *Heliyon*, 5 (9), 1–12. DOI: 10.1016/j.heliyon.2019.e02434.
- Schaufeli, W.B. (2018). Work engagement in Europe: Relations with national economy, governance and culture. *Organizational Dynamics*, 47, 99–106. DOI: 10.1016/j.orgdyn.2018.01.003.
- Shu-sheng, L. (2012). Culture Industry Development and Regional Economy – Case Study of Tianjin. *Physics Procedia*, 25, 1352–1356. DOI: 10.1016/j.phpro.2012.03.244.

- Varsakelis, N.C. (2001). The impact of patent protection, economy openness and national culture on R&D investment: a cross-country empirical investigation. *Research Policy*, 30 (7), 1059–1068. DOI: 10.1016/S0048-7333(00)00130-X.
- Yusof, F., Abdullah, I.C., Abdullah, F., & Hamdan, H. (2013). Local Inclusiveness in Culture based Economy in the Development of ECER, Malaysia: Case Study from Kelantan. *Procedia – Social and Behavioral Sciences*, 101, 445–453. DOI: 10.1016/j.sbspro.2013.07.218.

COMPANY CAPITAL STRUCTURE'S THEORETICAL FRAMEWORK: HISTORICAL ASSESSMENT AND TRENDS IN THE 21ST CENTURY

***Aija Pilvere-Javorska, Irina Pilvere, Baiba Rivža**

Latvia University of Life Sciences and Technologies, Latvia

*Corresponding author's email: apilvere@gmail.com

Abstract

Company capital is essential in running business and creating value added for the stakeholders, including economy. How the view on company's capital structure has evolved from theoretical perspective in the 20th century is needed to be assessed, in order to determine what concepts and theories, if any are relevant in the 21st century. Many theories have competed their way and transformed during the 20th century, while some, i.e. trade-off, signalling and stakeholder theories are still relevant in the 21st century. There are also new trends in the 21st century, new terms and quests shifting from determining and analysing optimal company's capital structure to sustainable finance, taxonomy and also sustainability in capital structure. Therefore, the aim of this research: to establish existing main theories impacting and analysing company's capital structure and to examine the theoretical shift of the theories based on the needs in the 21st century. Authors defined company's capital structure and determined that during the years 1989–2020, number of research publications has grown significantly, thus validating the need to reassess theoretical background of capital structure theories in the 20th century, as well as to help to determine the trends still relative and emerging from the theoretical and practical aspects to company's capital structure in the 21st century.

Key words: company capital structure, literature review, financial ratios, taxonomy, sustainability.

Introduction

In the 20th century, there has been a search to find an optimal company capital structure, as it is noted by S.C. Myers (1993). Capital is a tool, which is used in company to finance its assets and fund projects, which are beneficial and adding value to the company and also through the enterprise to the general economy. In other terms: capital is used in the company's business to generate income and profit. There is not much controversy in this statement, however, when looking at details, i.e. what composition of capital structure to have and what the capital structure is, if there is an ultimate optimal capital structure (Myers, 1993; Kraus & Litzenberger, 1973) for any firm, as well as whether taxes matter (Durand, 1952; Modigliani & Miller, 1958, 1959, 1963; Friedman, 1962, 1970), or whether agency/bankruptcy issues impact the way company chooses capital structure (Kraus & Litzenberger, 1973; Jensen & Meckling, 1976; Jensen, 1986) and when to attract funding (Demirguc-Kunt & Maksimovic, 1995; Baker & Wurgler, 2002), who the decision makers are (Friedman, 1962, 1970; Freeman, 1984, 2004; Donaldson & Preston, 1995) and what influences their decision to go with one or another type of capital (Donaldson, 1961; Myers & Majluf, 1984; Fama, 1970; Spence, 1973, 2002; Ross, 1977; Connelly *et al.*, 2011; Higgins, 1977), a variety of issues should be addressed. These are only some aspects of aforementioned topic, which researchers have already been discussing since the 20th century. How the view has changed is crucial in understanding what is still relevant and why in the 21st century in terms of company capital structure? Without capital no projects and company can exist and create added value for the economy. Theoretical development on how company capital structure has been viewed has

evolved significantly and more broadly during the 20th century and nowadays in the 21st century, there has been a shift to persistent view. In attempt to fully evaluate the subject, authors defined *the aim of this research*: to establish existing main theories impacting and analysing company's capital structure and to examine the theoretical shift of the theories based on the needs in the 21st century. Therefore, the following *tasks* were set: 1) to explain definition of the term company's 'capital structure' and assess its research topicality in 1989–2020; 2) to determine main capital structure historical theories and their developers in the 20th century; 3) to examine and define capital structure trends in the 21st century.

Materials and Methods

Authors have used scientific literature analysis and synthesis methods to perform the research and assessment of prevailing historical concepts of company capital structure theoretical framework and to establish trends in the 21st century. Capital structure in enterprises addresses the issues surrounding the choice of funding source, either it is debt or equity, the influencing parties in decision making and reasoning of the choice to use more debt or equity, as well as what conditions and assumptions impact that choice.

The research is organized as historical trend and theory review in first part, which follows with evaluation of most recent shifts in a company's capital structure analysis nowadays, which is creating a framework for further research topics in the future. Authors reviewed international scientific publications indexed in Scopus, Web of Science and other databases, performed a keyword search and analysis in the Web of Science database to establish the basis for this work and concept of company 'capital structure', focusing

on two main fields 'economics' and 'business finance' during years 1989–2020.

Limitations in this article is to evaluate capital structure from an enterprise perspective and its impacting components through the theory and previous researchers' publications to create a wide-ranging theoretical framework for company capital structure analysis further.

Authors chose to focus on available publication on historical company capital structure theories mainly from mid-20th century due to their availability up to the year 2020.

Results and Discussion

Company Capital Structure Composition: An Overview

When looking at the company capital structure, it is vital first to establish the definition of capital and its structure. Authors evaluated the capital structure from a company's perspective. Capital structure is found in each company's financial statements, namely the balance sheet: equity and liabilities part, and is presented in Figure 1.

Company's capital structure is formed based on 3 pillars: 1) first is equity, which is composed mainly of

shareholders' invested capital, representing book value of their shares and any premium if there is, reserves if any and retained earnings, that is known also as book value of the firm; 2) second pillar is borrowed sources or debt, which can come in various forms, most popular is either bank loans or issued bonds, for which interest is paid to the lender(s); 3) third source, which is less commonly discussed in classical capital structure literature is other liabilities, since the firm can be short-term financed based on the non-payment to accounts payables or on the extension of payment terms to the suppliers. According to authors: capital is a source for funding company's business to generate revenue in a sustainable way, it can be in a form either own (equity) or borrowed sources (debt), which have costs attached and may provide tax advantages.

For the scope of this research, authors mainly focus on evaluating first two sources of capital: equity and debt capital from theoretical perspective. There has already been for more than a century dilemma and also S.C. Myers (1993), emphasized that 'the optimal balance between debt and equity financing has been the central issue in corporate finance ever since Modigliani and Miller... Yet in practice it seems that financial leverage matters more than ever'.

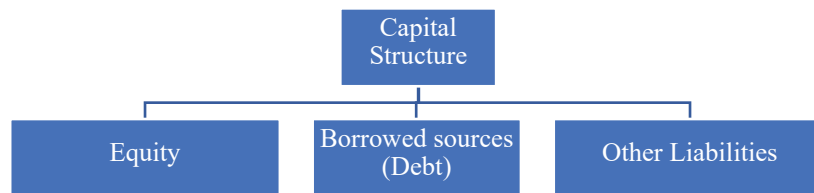


Figure 1. Company capital structure's main components.

Source: Author's designed.

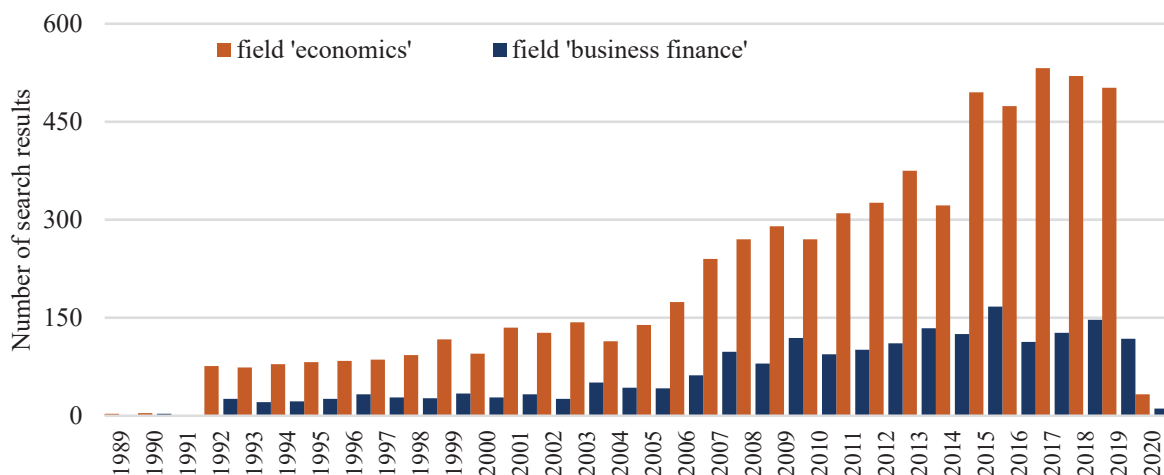


Figure 2. Keyword 'capital structure' in Web of Science database breakdown by main publication field in 1989–2020.

Source: Authors' compiled based on Web of Science database 1989–2020, created as of 22.02.2020.

While some authors, as R.G. King and R. Levine (1993) discussed, that capital impact has already been significant ‘in 1911 Joseph Schumpeter argued that the services provided by financial intermediaries—mobilizing savings, evaluating projects, managing risk, monitoring managers, and facilitating transactions are essential for technological innovation and economic development.’

The next question and task that authors put forward is an assessment of the topicality of the term ‘capital structure’ in scientific publications.

Thus, authors performed keyword ‘capital structure’ search in Web of Science database, and it can be observed that the number of publications in the field of economics are significantly more, almost 5 times exceeding number of scientific publications in the field ‘business finance’ (Figure 2). The prominent high number of research publications are to be found from the year 2015 up to 2019 in the field ‘economics’ on average 504 publications per year, and in the field ‘business finance’ 134, while high growth period was in the period 2005–2013, respectively where compound annual growth rate (CAGR) in the field of ‘economics’ was 12% and ‘business finance’ even more rapid 14% growth per annum was observed. In the last 5 years, the growth is smaller, while stable number of significantly almost four (field ‘economics’) or three (field ‘business finance’) times more scientific articles published per year when compared to the year 2005; thus, authors conclude that this topic has become more

researched and debated recently. This also corresponds to the authors’ view that capital structure is becoming more and more influential in the way companies run, and generate added value, while controversy as well exists, otherwise would not be so many publications in Web of Science in two most popular fields of more than 600 articles per year during each of last five years.

As authors mentioned earlier in this publication, this topic has already been reviewed from the beginning of the previous century, when online tools and access to the articles were mainly in the libraries. During more than 30 recent years (1989–2019), research publications are more indexed and available via web and accessible online from anywhere in the World. It also serves as one of the reasons of increasing popularity of the research in any topic, as well as international cooperation among scientists is becoming borderless. Several authors have tried to look from various perspectives and put forward multiple theories; how well these theories hold to the needs and necessities of the 21st century is yet to be determined. However, it is essential to understand various existing and developed company capital structure theories by historical scientific publications and research.

Historical Company Capital Structure Theories and Concepts

Authors attempted to compile main or most predominant capital structure theories from the previous century in Table 1.

Table 1

Capital Structure Theories and Concepts in the 20th Century

Theory name	Author(s), year, follow-up author(s)	Theory and concept overview
Net operating Income (NOI) and Net income (NI) theory	D. Durand (1952, 1959)	NOI: multiplying NOI with capitalization rate to obtain the value of the company, when subtract value of bonds. NOI includes interest. NI – same approach only NI is multiplied with determined capitalization rate. Income tax increases discrepancies between NOI and NI method, tax implication matters.
Modigliani and Miller (MM) theory	F. Modigliani, M.H. Miller (1958, 1963)	Initial publication (1958) is that taxes do not matter and capital structure itself is irrelevant to establish firm’s market value, later they publish (1963) correction that taxes do impact capital structure. Initial statement that cost of equity is not much higher than cost of debt financing, and that tax implications to the company’s market value are insignificant. In correction they acknowledge that tax advantages to debt financing are larger than they originally suggested. Their theory suggests to evaluate company’s value based on the assets they own or can be bought rather how they are financed, thus implying irrelevance of capital structure to determining enterprise’s value.
Pecking order theory	G. Donaldson (1961), S.C. Myers, N.S. Majluf (1984)	Theory is based on new project financing based on the cash flows and their timing, admitting that there is a risk associated with the debt. S.C. Myers and N.S. Majluf brought this topic further proving: if new projects are taken onboard that firms first prefer internal funds to debt.
Stockholder theory	M. Friedman (1962, 1970)	Stockholders select a businessman, who then decides how to use obtained capital of the company and taxes. Businessman is an agent for stockholders and has to improve their wealth and interests by any means. ‘Social responsibility’ is left to civil servants.

Theory name	Author(s), year, follow-up author(s)	Theory and concept overview
Market efficiency theory	E.F. Fama (1970)	Determined the definition: efficient market is one in which stock prices always reflect complete, available information. This is contrary to asymmetric information theory.
Signalling theory	M. Spence (1973, 2002), S.A. Ross (1977), B. Connelly et al. (2011)	Defines signalling: 'investors investment decision under uncertainty, as that of interpreting signals.' It is based on the available historical information in the market. The aim is to reduce existing information asymmetry between a signalling party and recipient or an interpreter of signal.
Trade-off theory	A. Kraus, R.H. Litzenberger (1973)	To optimize capital structure taking into account trade-off between debt tax advantage and bankruptcy penalties.
Agency and free cash flow theory	M.C. Jensen, W.H. Meckling (1976), M.C. Jensen (1986)	Agency problem: when there is a need to choose between paying out free cash flow to the shareholders as dividends or leaving it to the company and managers, who are paid to increase and grow the enterprise. This is particularly significant problem for a company with large free cash flows.
Debt capacity theory	R. Higgins (1977)	Determine the notion on how much debt a company can take on, search and define sustainable growth rate of an enterprise.
Stock market development and choice of financing theory	A. Demirguc-Kunt, V. Maksimovic (1995)	Determined that stock market development is negatively correlated with leverage in developed market, while positively correlated in developing markets. Stock market development in developing market results in higher debt to equity ratio for the firms.
Stakeholder theory	R.E. Freeman (1984, 2004), T. Donaldson, L.E. Preston (1995)	Redefined stakeholder as 'any group or individual that can affect or is affected by the achievement of corporation purpose' – company's success depends on relationship between stakeholders and management. Further developed by T. Donaldson (1995).
Market timing of stock issuance theory	M. Baker, J. Wurgler (2002)	They summarized managers and company's decision, when to issue and repurchase stock: issue when managers believe it is overvalued and repurchase when it is undervalued by the market based on historical book values. This implies and focuses of market-to-book values impact on capital structure and correlates with historical market value of the firm.

Source: Authors created.

One of the first authors to look into company's capital structure and how it impacts enterprise's value in mid-20th century was D. Durand (1952), who looked at net operating income and net income, to establish company's value, using capitalization rate. Initially, D. Durand (1952) capital structure proposition based on NOI and NI was developed and published in 1952, where D. Durand focuses on maximizing income rather than investment value. At almost the same time only a few years later – in 1958 also prominent initial MM theory was announced. This created a controversy, which is also noted by S.C. Myers (1977), who was one of the first to refer to D. Durand as being one of the early critiques to MM theory. D. Durand (1959) commented on MM theory and via the same issue of the American Economic Review (AER) Vol. 49 (4) in 1959 also F. Modigliani and M.H. Miller (1959) issued a reply to his comment, as well as other authors debated on the issue there. Controversial issue was that initially MM theory put forward a notion that cost of capital, capital structure and tax implications are insignificant determining company's value, that is that enterprise value is not

affected by leverage, that the main emphasis on company's value is net assets that a company holds. Five years later F. Modigliani and M.H. Miller (1963), published a correction, where they acknowledged that tax implication has a larger effect on the leverage and debt than they thought before. Other proposition was that leverage enlarges the risk and impacts return to shareholders, which is also in line with D. Durand (1952), G. Donaldson (1961), S.C. Myers, N.S. Majluf (1984) findings. Following theory, established initially by G. Donaldson (1961) was the pecking order theory, which states that the company prefers its own funds over debt, acknowledging that there is a risk associated with the debt to the enterprise, and that new project financing is based on the availability of cash flows and their timing. This theory was later updated to the aforementioned definition by S.C. Myers, N.S. Majluf (1984), stating that when new projects are brought on board the company would prefer its own funds to debt. This theory actually hints also to another aspect, not mentioned before: information asymmetry theory, that some parties, in particular company managers have more information

about the enterprise, when compared to the investors or public in general. This notion is also underlying factor for other later developed theories, in particular developed by M. Baker and J. Wrugler (2002), who defined market timing of stock issuance theory, based on the existence of information asymmetry concept. In the meantime, other controversial aspect was popular in mid /late 20th century among researchers, was the notion that there is perfect information available and presented about company and is fully reflected in the stock market prices.

Aforementioned authors evaluated taxes, and importance or relevance of capital structure, while other researchers evaluated the topic from the view point who involved decision makers are and possible conflicts between them: some of most prominent were M. Friedman (1962, 1970) with stockholder theory, and R.E. Freeman (1984, 2004), where he expanded shareholder (stockholder) explanation to stakeholder's theory. This in turn, was further analysed also by T. Donaldson, L.E. Preston (1995).

R. Higgins (1977) attempted to assess on how much of one component 'debt' firm can take on, additionally trying to link the term to 'optimal growth', as explaining 'the optimal growth, therefore, it is not simply the outgrowth of accepting all average risk investment opportunities yielding a return above firm's cost of capital as conventionally calculated. Instead, management must explicitly consider the tradeoffs between more growth and some combination of leverage and less dividends'. His theory links to the trade-off theory developed by A. Kraus, R.H. Litzenberger (1973).

Other widely known researcher in the field of finance is E.F. Fama (1970), his efficient market theory, defined in 1970, states that stock market is in the way transparent and that stock prices reflect completely available information. This statement contradicts with other theory that is information asymmetry theory, where researchers M. Baker and J. Wrugler (2002) in their market timing of stock issuance theory claim that new stock will be issued when managers believe it is overvalued and repurchased when stock is undervalued. This implies that managers have more information than stock market has reflected. A. Demirguc-Kunt and V. Maksimovic (1995), took a step further to determine if the stock market development, which is company's choice going for equity or bond capital to the stock market, does impact whether the stock market analysed is in developed country or developing country. Since in the developing countries, where stock markets are less developed and banks have almost monopolized financing market, banking industry is fearful of stock market development and losing their monopoly status. A. Demirguc-Kunt and V. Maksimovic (1995), discovered two parallel,

though opposite trends: being that in the developed markets there is negative correlation between stock market development and leverage, if there is a positive correlation in developing markets, where more significant stock market development leads to enterprises' higher debt to equity ratios. They note that analysis of capital structure is done using companies' financial ratios, that is, for instance, debt to equity ratio. Their theory and analysis correspond to the previously developed signalling theory by M. Spence (1973). Signalling theory implies that investors interpret signals from available historical information, which is available in market, i.e. job market. Authors believe that financial ratios are perfect example of signalling theory, since calculated financial ratios is based for listed companies on their historical performance, while in the times of uncertainty, they are used as proxy for future results or trends. M. Spence (2002) evolved the theory further, that signalling theory is helping to reduce information asymmetry, which exists, 'the issue, of course, was that signals are not terribly complicated things in games where the parties have the same incentives, i.e., where there is a commonly understood desire to communicate accurate information to each other'. As B. Connelly et al. (2011) state in respect to information asymmetry 'some information is private, information asymmetries arise between those who hold that information and those who could potentially make better decisions if they had it'. Another historical theory which looks at financial ratios, is trade-off theory: according to G. Campbell and M. Rogers (2018) 'according to the static trade-off theory, companies should have a target leverage ratio which balances the benefits and costs of debt.' H. DeAngelo and R. Roll (2015) opened a new type of discussion in capital structure analysis focusing on ratios that 'capital structure stability is the exception, not the rule, occurs primarily at low leverage, and is virtually always temporary, with many firms abandoning low leverage during the post-war boom.'

Capital Structure Trends in the 21st Century

In section 2, authors discussed theories, which were developed mainly during the 20th century, leaping into the beginning of the 21st century. One of the recent trends in the 21st century is the usage of the term "sustainability" although this term was already mentioned by R. Higgins (1997) who was debating and attempted to calculate sustainable growth rate of the company. However, only at the beginning of the 21st century the term and topic on sustainability was getting voiced more and more. United Nations Environment Programme's (UNEP) role was increased at the United Nations (UN) Conference on Environment and Development, in 1992, where the emphasis was placed on promoting sustainable

development: 'development that meets the needs of the present without compromising the ability of future generations to meet their own needs'. Only last year the European Commission (EC) (2019) 'has welcomed today's political agreement between the European Parliament and the Council on the creation of the world's first-ever 'green list' – a classification system for sustainable economic activities, or taxonomy.' This also serves as a definition of term 'taxonomy' which is closely linked to 'sustainable finance'. Here, talks are about investment activities, while the question about sustainable company capital structure – has it yet embarked on the financial statements in the Nordic countries, which are considered more 'green thinking' when compared to the Baltic States? That's yet the question to resolve, but it is beyond the scope of this publication. There have already been authors in the 21st century taking into consideration sustainability and finance, while very limited research has been on empirical evidence of what that means for the companies and how and if there has been a shift towards sustainable company capital structure and what this term means. V.Cantino et al. (2017) were trying to link Environmental, Social, Governance (ESG) and financial capital structure, while looking at ESG impact on cost of equity and cost of debt and 'literature is unanimous on the positive effect that ESG factors have on the cost equity decline, so an increase of ESG activities affects a lowering cost of equity. Results show that the main reasons of its reduction can be ascribed to the asymmetric information decreasing'. They are not looking at the capital structure composition change or dynamics and interlinking drivers of capital structure formation besides cost of either equity or debt. Researchers M.P. Sharfama and C.S. Fernando (2008) state that 'if the firm makes 'greener' (i.e. more efficient) use of its resources, generating less pollution and waste from the resources employed, it will be more economically effective'. They analysed a sample of 267 U.S. companies in terms of leverage, cost of debt et al. they are one of the first ones trying to search and explain sustainability and link with capital structure and financials on empirical level. R.E. Freeman (1984) developed stakeholder theory is still topical, and according to R.E. Freeman et al. (2010), "stakeholder theory' or 'stakeholder thinking' has emerged as a new narrative to understand and remedy three interconnected business problems – the problem of understanding how value is created and traded, the problem of connecting ethics and capitalism, and the problem of helping managers think about management such that the first two problems are addressed'. They emphasized that has to be done from ethical and sustainable way of creating value.

Conclusions

Capital structure theoretical framework has been a dynamic concept with focus on searching for optimal company capital structure in the 20th century, while intending to cover, what it does or doesn't impact, with some famous researchers going head to head with each other, bringing out even better definitions and concepts, like F. Modigliani and M.H. Miller, S.C. Myers and T. Donaldson. Other scientists are looking at who the ones making decisions on capital structure are and who the ones impacted by it are, i.e. stockholder and stakeholder theories, while in the 21st century focus has remained on stakeholders.

In the meantime, there has emerged a new trend in company's capital structure and economy in general: the term taxonomy, which attempts to define and classify sustainable economic activities. Authors evaluate that this topic and trend is needed to be researched further on empirical level in the 21st century. The analysis is needed how it extends to the companies and their capital structure, if the company uses its finance and capital structure in a sustainable way while creating added value and how and whether it has already impacted its profits and returns. The other theory, which has remained topical during both centuries is signalling theory, where the ratios and indicators, which can signal of the state, where the company is in the investment and finance universe and to be comparable over historical period. This theory can highlight changes based on the signals interpreted on what to expect in terms of taxonomy and what direction company's capital structure is changing. Further research needs to be done in terms of extended empirical analysis to evaluate how signals and stakeholders within companies and regions are moving towards sustainability in terms of capital structure and finances in creating value.

This topic is crucial for global institutions setting the rules for sustainability, as well as local policy makers, who then need to implement it and companies who are directly impacted by those decisions. Nevertheless, researchers and academia could benefit from the future analysis and theoretical evaluation how empirical results correspond to existing theories and how these theories are evolving, and what trends are emerging.

Acknowledgements

The research was supported by the National Research Programme 'Latvian Heritage and Future Challenges for the Sustainability of the State' project 'Challenges for the Latvian State and Society and the Solutions in International Context (INTERFRAME-LV)'. The publication was funded by grant 'Strengthening Research capacity in the Latvia University of Life Sciences and Technologies' project No. Z39.

References

- Baker, M., & Wurgler, J. (2002). Market Timing and Capital Structure. *The Journal of Finance*. Vol. LVII, No. 1, Feb. 2002.
- Campbell, G., & Rogers, M. (2018). Capital structure volatility in Europe. *International Review of Financial Analysis*. No. 55, pp. 128–139.
- Cantino, V., Devalle, A., & Fiandrino, S. (2017). ESG Sustainability and Financial Capital Structure: Where they Stand Nowadays. *International Journal of Business and Social Science*. Vol. 8, No. 5, May 2017, pp. 116–126.
- Connelly, B., Certo, T., Ireland, R.D., & Reutzel, C.R. (2011). Signaling Theory: A Review and Assessment. *Journal of Management*. Vol. 37(1), January 2011, pp. 39–67. DOI: 10.1177/0149206310388419.
- DeAngelo, H., & Roll, R. (2015). How stable are corporate capital structures? *Journal of Finance*. Vol.70 (1), pp. 373–418.
- Demirguc-Kunt, A., & Maksimovic, V. (1996). Stock Market Development and Financing Choices of Firms. *The World Bank Economic Review*. Vol. 10, Issue 2, May 1996, pp. 341–369.
- Donaldson, G. (1961). Corporate Debt Capacity: A Study of Corporate Debt Policy and the Determination of Corporate Debt Capacity. Book: Division of Research, Graduate School of Business Administration, Harvard University.
- Donaldson, T., & Preston, L.E. (1995). The Stakeholder Theory of the Corporation: Concepts, Evidence, and Implications. *The Academy of Management Review*. Vol. 20, No. 1, Jan., 1995, pp. 65–91.
- Durand, D. (1952). Cost of Debt and Equity Funds for Business: Trends and Problems of Measurement. *National Bureau of Economic Research*. pp. 215–262, Retrieved January 10, 2020, from <http://www.nber.org/chapters/c4790.pdf>.
- Durand, D. (1959). The Cost of Capital, Corporation Finance, and the Theory of Investment: Comment. *The American Economic Review*. Vol. 49(4), pp. 639–655. Retrieved February 15, 2020, from www.jstor.org/stable/1812918.
- European Commission (2019). Retrieved February 29, 2020, from https://ec.europa.eu/commission/presscorner/detail/en/ip_19_6793, December 18, 2019.
- Fama, E.F. (1970). Efficient Capital Markets: A Review of Theory and Empirical Work. *Journal of Finance*. Vol. 25, No. 2, pp. 383–417.
- Freeman, R.E. (2004). The Stakeholder Approach Revisited. DOI: 10.5771/1439-880X-2004-3-228.
- Freeman, R.E. (1984). Book Strategic management: A stakeholder approach. Boston: Pitman
- Freeman, R.E., Harrison, J.S., Wicks, A.C., Parmar, B., & de Colle, S. (2010). Stakeholder Theory. *The state of the art*, 62 p.
- Friedman, M. (1962). Capitalism and Freedom. Book: The University of Chicago Press, Chicago 60637, reprint 1982.
- Friedman, M. (1970). The Social Responsibility of Business is to Increase its Profits. *The New York Times Magazine*.
- Higgins, R. (1977). How much growth can a firm afford. *Financial Management*, Vol. 6, No. 3, Autumn, 1977, pp. 7–16.
- Jensen, M.C. (1986). Agency Costs of Free Cash Flow, Corporate Finance, and Takeovers. *The American Economic Review*, Vol. 76, No. 2, Papers and Proceedings of the Ninety-Eighth Annual Meeting of the American Economic Association, May, 1986, pp. 323–329.
- Jensen, M.C., & Meckling, W.H. (1976). Theory of the firm: Managerial behavior, agency costs and ownership structure. *Journal of Financial Economics*. Vol. 3, Issue 4, October 1976, pp. 305–360.
- Kraus, A., & Litzenberger, R.H. (1973). A State-Preference Model of Optimal Financial Leverage. *The Journal of Finance*. Vol. 28, No. 4, September, 1973, pp. 911–922.
- Modigliani, F., & Miller, M.H. (1958). The Cost of Capital, Corporation Finance and the Theory of Investment. *The American Economic Review*, Vol. XLVIII, June 1958, No 3.
- Modigliani, F., & Miller, M.H. (1963). Corporate Income Taxes and the Cost of Capital: A Correction. *The American Economic Review*. Vol. 53, No. 3, June, 1963, pp. 433–443.
- Modigliani, F., & Miller, M.H. (1959). The Cost of Capital, Corporation Finance, and the Theory of Investment: Reply. *The American Economic Review*, Vol. 49(4), pp. 655–669. Retrieved February 15, 2020, from www.jstor.org/stable/1812919.
- Myers, S.C. (1977). Determinants of Corporate Borrowing. *Journal of Financial Economics*, Vol. 5, pp. 147–175.
- Myers, S.C., & Majluf, N.S. (1984). Corporate Financing and Investment Decisions when Firms have Information that Investors Do Not Have. *Journal of Financial Economics*. Vol. 13, pp.187–221.

- Myers, S.C. (1993). Still Searching for Optimal Capital Structure. *Journal of Applied Corporate Finance*. pp. 80–105. Retrieved December 10, 2019, from <https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1745-6622.1993.tb00369.x>.
- King, R.G., & Levine, R. (1993). Finance and Growth: Schumpeter Might be Right. *The Quarterly Journal of Economics*. Vol. 108, No. 3, August, 1993, pp. 717–737.
- Ross, S.A. (1977). The Determination of Financial Structure: The Incentive-Signalling Approach. *The Bell Journal of Economics*. Vol. 8, No. 1, Spring, 1977, pp. 23–40.
- Sharfama, M.P., & Fernando, C.S. (2008). Environmental risk management and the cost of capital. *Strategic Management Journal*. Vol. 51(2), pp. 315–334. DOI: 10.1002/smj.
- Spence, M. (1973). Job Market Signaling. *The Quarterly Journal of Economics*. Vol. 87, No. 3, August, 1973, pp. 355–374.
- Spence, M. (2002). Signaling in Retrospect and the Informational Structure of Markets. *The American Economic Review*. Vol. 92, No. 3, June, 2002, pp. 434–459.
- United Nations Environment Programme. Retrieved February 29, 2020, from <https://www.unepfi.org/about/background/>.
- Web of Science database, Retrieved February 22, 2020, from <https://llufb.llu.lv/lv/datubazes-un-katalogi/abonetas-datubazes-e-zurnali-e-gramatas#WebScienceDB>.

CUSTOMER-BASED BRAND EQUITY CREATION FOR ONLINE GROCERY STORES

*Miglė Šontaitė-Petkevičienė

Vytautas Magnus University, Lithuania

*Corresponding author's email: migle.sontaite-petkeviciene@vdu.lt

Abstract

Given the growing worldwide tendencies of online shopping and increasing popularity of online grocery shopping, building customer-based brand equity for online grocery stores is gaining its popularity among business owners and marketers. Building good customer-based brand equity is considered to be one of the crucial goals for online businesses that leads to successful competition and good customer experience. The aim of this research is to determine customer-based brand equity dimensions for online grocery stores. To reach the aim, this paper adopts analysis and synthesis of scientific and practical literature in the field of customer-based brand equity and empirical research of three stages: field analysis, expert interviews and customer survey. 33 dimensions of customer-based brand equity for online grocery stores grouped in 8 dimension clusters were generated from the field analysis and expert interviews. Generated dimensions were provided for the evaluation during the customer survey. Empirical research proved 31 valid dimensions of customer-based brand equity for online grocery stores evaluated as very relevant, relevant and of average relevance. Main drivers of customer-based brand equity for online grocery stores that proved to be very relevant are: saving time, good price, fresh products, quality of service, and reputation of retail chain behind.

Key words: customer-based brand equity, brand equity, branding, customer behaviour, e-commerce, retail.

Introduction

The construct of customer-based brand equity has gained a wide interest from theory as well as practice. Creation of customer-based brand equity has become one of the most important tendencies in branding and management of business organizations. In addition, online retailers are coming to realize that they have much to learn in this area and that customer-based brand equity is particularly appealing in the online shopping. Despite the fact that Lithuania and other EU countries are living in the world of booming popularity of online grocery shopping, customer-based brand equity creation for online grocery stores is quite a new topic. It is argued that this field lacks knowledge and tools to build value for customers. Consequently, the question is not whether online grocery stores should build customer-based brand equity but how it should be done.

This paper focuses on dimensions of customer-based brand equity for online grocery stores. The purpose of this research is to answer the question how to build customer-based brand equity for online grocery stores. The object of the research is customer-based brand equity for online grocery stores. The aim of this research is to determine customer-based brand equity dimensions of online grocery stores.

The objectives of the paper are as follows: to analyse theoretical conceptualizations of customer-based brand equity and its creation; to identify customer-based brand equity dimensions for online grocery stores by using field analysis and expert interviews; to evaluate the relevance to customer-based brand equity dimensions of online grocery stores by using customer survey method.

The paper consists of both theoretical and empirical analysis. The research methods used in the paper include logical analysis, generalization and

interpretation of scientific and practical literature. After the presentation of theoretical insights, research methodology is outlined, following with empirical research findings. Finally, conclusions are stated.

Given the intensified competition in the retail industry and booming popularity of online groceries shopping, a better understanding of customer-based brand equity is strategically important for online grocery stores. Consumer-based brand equity receives significant attention from the academic and business communities (Cifci *et al.*, 2016); however, a review of customer-based brand equity literature demonstrates that: (a) despite the rich literature on customer-based brand equity, lack of consensus on its conceptualization and operationalization remains; (b) most of the studies focus on a limited number of customer-based brand equity facets, thus failing to provide a more holistic view of the customer-based brand equity process; (c) there is a scarcity of studies that integrate key consumer behavioural outcomes into the customer-based brand equity formation process (Chatzipanagiotou, Christodoulides, & Veloutsou, 2019). Anselmsson, Burt & Tunca (2017) draw attention to the fact that retailers are amongst the world's strongest brands, but little is known about retailer customer-based brand equity. They argue that current operational models are too abstract for understanding the uniqueness of the retail industry and too simplistic to understand the interrelationships among the dimensions in the retailer brand equity building process.

Various authors agree that consumer-based brand equity provides a number of positive outcomes for organizations. Consumer-based brand equity is essential for driving customer equity, differentiating brands, assessing brand performance and gaining competitive advantage in the marketplace (Cifci *et al.*, 2016). Keller, Aperia & Georgson (2012) argue

that a brand with positive customer-based brand equity results in consumers being more accepting of a brand extension, less sensitive to price increases and withdrawal of advertising support or more willing to seek the brand in a new distribution channel. Troiville, Hair & Cliquet (2019) add that retailer customer-based brand equity affects customer attitude, loyalty and word-of-mouth. An example of the importance of retailer brand equity is evidenced by the annual report of Deloitte (2019): retailers have to find ways to distinguish themselves from competitors in order to succeed. That means having strong customer-based brand equity, offering consumers superior shopping experiences, and being clearly differentiated from competitors. Customer-based brand equity appears to be a major construct and retailers should take advantage of it because the equity of the retailer should serve to increase the retailers: a) share of wallet (by increasing the money spent in its owned stores); b) market share (by adding up the current and new customers due to its attraction); c) power against competitors within the marketplace; d) bargaining power against manufacturers and suppliers in the vertical channel; e) efficiency (by a cost reduction); and f) revenue and profits (Troiville, Hair, & Cliquet, 2019).

Keller, Aperia & Georgson (2012) define customer-based brand equity as the differentiated effect that brand knowledge has on consumer response to the marketing of that brand. A brand is said to have positive customer-based brand equity when consumers react more favourably to a product and the way it is marketed when the brand is identified than when it is not. However, Troiville, Hair & Cliquet (2019) argue that a specific conceptual definition adapted to retailers remains to be developed and validated.

Keller, Aperia & Georgson (2012) distinguish two main sources for customer-based brand equity: brand awareness and brand image. According to Aaker (1991), customer-based brand equity has four dimensions: perceived quality, brand awareness, brand loyalty and brand associations. Cifei *et al.* (2016) distinguish 6 customer-based brand equity dimensions: brand awareness, physical, staff behaviour, ideal self-congruence, brand identification, lifestyle-congruence. Nam, Ekinici & Whyatt (2011) argue that customer-based brand equity is created based on 7 dimensions: physical quality, staff behaviour, ideal self-congruence, brand identification and lifestyle congruence, brand satisfaction and brand loyalty.

However, Troiville, Hair & Cliquet (2019) believe that existing customer-based equity frameworks are usually product-based and, consequently not appropriate and should not be used when it comes to conceptualizing the brand equity of retailers.

Anselmsson, Burt & Tunca (2017) agree to this notion stating that there are several examples of retailer equity scales, but because these scales are based on general models, they currently fail to capture important dimensions that are unique to the retailing industry. As Troiville, Hair & Cliquet (2019) explains, retailers typically build customer-based brand equity by enhancing the product value and the experiential value, but still have no effective means to operationalize and measure it.

Anselmsson, Burt & Tunca (2017) argue that retailer specific dimensions should be better reflected in retailer brand equity measurement models. Troiville, Hair & Cliquet (2019) in their research distinguished 7 retailer customer-based brand equity dimensions: access, assortment, atmosphere, convenience, employees, quality, value and private brands. While Anselmsson, Burt & Tunca (2017) presented a retailer brand equity scale, which as they say provides high predictability of core dimensions such as brand trust and loyalty and, is comprehensive including both general brand equity dimensions and retail industry specific dimensions. Their scale consists of 17 items grouped to 4 factors: awareness, product quality, customer service, pricing policy, retailer trust, physical store, loyalty.

Existing frameworks prove that customer-based brand equity frameworks are context specific. Therefore, it is possible to argue that customer-based brand equity dimensions of online grocery stores might be different. That is why it is possible to state that customer-based brand equity should be treated in terms of specific industries meaning customer-based brand equity of online grocery stores might demonstrate specifics compared to other industries.

Materials and Methods

To achieve the aim of the paper, this research adopts analysis and synthesis of scientific and practical literature in the field of customer-based brand equity creation. In order to theoretically determine how customer-based brand equity is built and managed, general scientific research methods were applied – systematic analysis, evaluation, generalization, comparison and abstraction.

Furthermore, to identify customer-based brand equity dimensions of online grocery stores, the empirical research was carried out. Three different empirical research methods have been used: qualitative field analysis, expert interviews and customer survey. At first, field analysis of market data from secondary sources was performed. Qualitative field analysis, as well as findings of academic and scientific researches helped to construct the set of customer-based brand equity dimensions for the online grocery stores. These findings were discussed during the following

Table 1

Methods of empirical research

Parameters of research	Research methods and their characteristics		
	First stage of research	Second stage of research	Third stage of research
1. Nature of research	Exploratory research	Exploratory research	Descriptive research
2. Object of research	Dimensions of customer-based brand equity for online grocery store		
3. Order of research	Onetime (short-term)		
4. Level of research	National		
5. Type of data	Secondary data	Primary data	
6. Method of research	Field analysis	Semi-structured interviews	Survey on internet
7. Instrument of data collection	Online search using keywords	Questionnaire	Questionnaire
8. Type of questions	-	Open	Open and closed (scale and optional)
9. Type of scale	-	-	Likert scale
10. Number of values	-	-	5
11. Method of measurement	Qualitative	Qualitative	Quantitative
12. Sample of research	-	Purposive nonprobability	

step – conducting interviews with representatives of online grocery stores. Insights collected during expert interviews amended collected data with the internal point of view. Finally, at the third stage of empirical research – the anonymous online customer survey – has been performed. Methods used during empirical research are outlined in Table 1.

Field analysis. Secondary data from external sources was used to perform field analysis, which includes online grocery stores market overview in Lithuania. Online grocery stores market presentation is based on external data by evaluating product portfolio structure, competitive advantage, resources, capabilities, market development trends and possible dimensions of customer-based brand equity.

Expert interviews. In order to gather internal insights on customer-based brand equity creation for online grocery stores, informal semi-structured interviews have been performed. Live interview method was chosen in order to gather primary data from the representatives of 2 online grocery stores that operate in Lithuania. An individually prepared questionnaire was used as the basis for these interviews. Two marketing managers representing two different online grocery stores were asked to share their ideas about the current setup of the company (and its suitability to serve customers' needs efficiently), current customer-based brand equity creation status and future vision and the main challenges related to this issue. The interviews were conducted in the form of live meetings and discussions, providing guidance for possible answers and asking for clarification or elaboration if necessary. The questionnaire for expert interviews consisted of 9 open questions. Before

starting interviews, experts were introduced with the aim of the discussion, its logic and expected result. Semi-structured interviews were organized in January, 2020. The duration of each interview was ~15–30 minutes.

As the exploratory research can only describe content of problem, generate ideas and insights, and determine variables for the descriptive research, results of exploratory research were considered mediate and modifiable during the descriptive research. Data from questionnaires helped to determine dimensions of customer-based brand equity from the point of view of online grocery stores' representatives, provided information which aspects of customer-based brand equity are considered as the most important by the companies. Based on the insights collected from the expert interviews, customer survey questionnaires were prepared.

Customer survey. The survey was constructed and distributed using a web-based platform SurveyMonkey. 342 questionnaires that were collected during descriptive research were processed and analysed. It is presumed that a sample of descriptive research was representative. Answers from customer survey allowed to identify and evaluate customer-based brand equity dimensions that are most important for the customers of online grocery stores. To participate in the survey respondents had to comply with one condition – to be a customer of online grocery store. This means that they had to purchase at least once from at least one of the online grocery stores. Respondents of customer survey were asked to evaluate the importance of customer-based brand equity dimensions for the online grocery store.

Evaluation of the online grocery stores' customer-based brand equity dimensions allowed to calculate average meanings of each dimension and distinguish most important aspects that online grocery stores should focus on while building their customer-based brand equity. Since this empirical research is a three-stage research using three different research methods, it is considered to provide trustworthy results.

Results and Discussion

This section provides results from three stages of empirical research: qualitative analysis, expert interviews and customer survey.

Field analysis. Field analysis of market data from secondary sources was performed in order to do an online grocery stores' market overview. Lithuanian online grocery stores market was analysed by evaluating product portfolio structure, competitive advantages, resources, capabilities, market development trends and possible dimensions of customer-based brand equity. Results from the field analysis allowed to determine the level of customer-based brand equity that Lithuanian online grocery stores are building and identify possible dimensions of customer-based brand equity for online grocery stores.

First online grocery store in Lithuania Zzz.lt was introduced into the market in 2015. Two years later, it stopped its existence. They had a hard task – to change Lithuanians' buying behaviour, educate people and earn trust, since they were innovators in Lithuanian market – first online grocery store. Another important reason for their failure was considered the fact that it was a start-up without any retail chain behind. However, their ambitions were very big – they started from zero in all Lithuanian cities right away from the beginning.

At the moment, two online grocery stores operate in Lithuania: Barbora (as part of Maxima group) and LastMile (partner of IKI retail chain). Both online grocery stores – Barbora and LastMile – are introduced into the market by different Lithuanian retail chains. Following the tendencies of online shopping growth, another retail chain Rimi has plans to introduce their online grocery store to market in 2020 first quarter. This will be the third player in deliberately small Lithuanian market.

Retail chain Maxima introduced Barbora brand into Lithuanian market in 2014. This online grocery store was first introduced into two largest cities of Lithuania – Vilnius and Kaunas. In 2017, Barbora started operating in Klaipėda, too. At the moment, Barbora operates in 11 Lithuanian cities. In 2018, Barbora entered Latvian and Estonian markets (Budzinauskienė, 2018). In 2018, the growth of Barbora reached 50%, mostly influenced by its market expansion (M360, 2019). CEO of Barbora in

his interview highlighted main priorities of Barbora: further development, improvement of services quality and customer experience, introduction of innovative and environment friendly solutions (M360, 2019). Main advantages for customers outlined in Barbora. Its webpage are as follows: saving precious time of customers; taking advantage of attractive offers and discounts; selection of fresh and high-quality products; receipt of 1% on the amount of purchases in Maxima money (Barbora official website, 2020). Barbora brand's slogan is 'More time for yourself'. In 2018, Barbora introduced a new technology for order pickup – 'Click&Collect' self-service food terminals with 3 different temperature zones. CEO of Barbora stated that the new technology provides more opportunities for customers, allows better time planning, customers do not depend on courier arrival time, and it allows to pick up order when Barbora is closed (Budzinauskienė, 2018). Barbora delivers order by using highly recognizable red trucks that has a visible brand and ensures required temperature for product deliveries. Customers can pay for their orders using different payment methods. Barbora online grocery store offers wide selection of vegetables, fruits, meat, bakeries, dairy products, drinks and commodity goods. CEO of Barbora distinguishes quality as their main goal. In the future, they intend to expand their product portfolio and offer express delivery service. Another important development direction is expansion of service offering customers a wide selection and freedom. Third direction is attention to citizenship and waste reduction (Juškauskaitė, 2019).

In 2019, another online grocery store started delivering groceries to Lithuanians. Lithuanian people had the possibility to order groceries from physical retail store IKI by using an app of Lithuanian start-up LastMile. They started in Vilnius. However, few months later another city – Kaunas – was added (Mikoliūnaitė, 2019). Their competitive advantage was based on a shared economy principle as LastMile allows orders and deliveries not only from IKI, but also from other shops. LastMile positions itself as an online shopping centre that has many shops (Vizbarienė, 2019). Differing from their main competitor – Barbora, they use independent couriers for the deliveries. Another competitive advantage is very fast delivery of fresh products. As a marketing manager of LastMile stated, their significance is speed of delivery, they call it an instant delivery. None of the competitors can offer faster delivery, because they use shared economy model when deliveries are made by citizens (Chockevičiūtė, 2019). Also, this helps to build LastMile brand as a socially responsible brand. Communication manager of IKI states that they are researching possibilities for improved customer experience, usage of technological advantages and

Table 2

Dimensions of customer-based brand equity for online grocery store

Clusters of dimensions	Dimensions	Source		Relevance	
Customer focus	customer experience	FA		4.3	Relevant
	quality of service	FA	EI	4.5	Very relevant
	customer service	FA	EI	4.3	Relevant
	convenient app	FA		4.1	Relevant
	word-of-mouth		EI	3.9	Relevant
Product quality	wide product portfolio	FA		4.1	Relevant
	fresh products	FA		4.6	Very relevant
	high quality products	FA	EI	3.8	Relevant
	value for money	FA		4.4	Relevant
Delivery amenities	fast delivery	FA	EI	4.4	Relevant
	express delivery (within 1 h 30 min)	FA		3.0	Average relevance
	free delivery	FA		4.2	Relevant
	deliveries by independent couriers (citizens)	FA		2.3	Low relevance
	saving time		EI	4.8	Very relevant
Financial benefits	good price	FA		4.7	Very relevant
	attractive offers and discounts	FA		4.3	Relevant
	money returns from purchases, retail chain money	FA		2.9	Average relevance
	collection of points	FA		2.4	Low relevance
Alternative choices	self-service food terminals	FA		3.7	Relevant
	different payment methods	FA		3.9	Relevant
	possibility to combine shops in one order	FA		4.2	Relevant
Innovativeness	innovative solutions	FA		3.6	Relevant
	new services	FA		3.2	Average relevance
Brand	reputation of retail chain behind	FA		4.5	Very relevant
	brand awareness	FA		4.1	Relevant
	brand associations		EI	4.3	Relevant
	trustworthy brand		EI	4.2	Relevant
	market influencer		EI	4.0	Relevant
Responsibility	environment friendly solutions	FA		3.8	Relevant
	citizenship	FA		3.3	Average relevance
	waste reduction	FA		3.6	Relevant
	eco-friendly packaging	FA		3.9	Relevant
	socially responsible brand	FA		4.2	Relevant

Note: sources are coded (FA-field analysis, EI-expert interviews).

offering qualitative assortment and time saving (Juškauskaitė, 2019).

As the rest of retail chains that operate in Lithuania – Lidl and Norfa – are also planning of starting online groceries shopping possibilities – it is worth to analyse what dimensions of existing online grocery stores build customer-based brand equity. The results would help the later competitors to have a more successful start of business and build value to customers from the first days of existence.

Based on the qualitative field analysis it is possible to identify possible customer-based brand equity dimensions for the online grocery stores. After analysis of publications in the media and retail chains' websites the author of this paper was able to distinguish 28 possible dimensions of customer-based brand equity for the online grocery stores: fast delivery; express delivery (within 1 h 30 min); customer experience; innovative solutions; environmentally friendly solutions; attractive offers

and discounts; wide product portfolio; fresh products; high quality products; money returns from purchases, retail chain money; collection of points; self-service food terminals; reputation of retail chain behind; brand awareness; value for money; different payment methods; good price; quality of service; new services; citizenship; waste reduction; eco-friendly packaging; convenient app; possibility to combine shops in one order; free delivery; deliveries by independent couriers (citizens); socially responsible brand; customer service. The above mentioned 28 possible dimensions extracted from the field analysis are listed in Table 2 using a code FA (field analysis).

Expert interviews. Second stage of empirical research – expert interviews – were done in order to gather internal insights on customer-based brand equity dimensions for online grocery stores. Live informal semi-structured interviews have been performed with representatives of 2 Lithuanian online grocery stores – Barbora and LastMile. Two marketing managers representing both online grocery stores were asked to share their ideas about the current setup of the company (and its suitability to serve customers' needs efficiently), current customer-based brand equity creation status and future vision, the main challenges related to this issue.

Experts informed about customer surveys confirming the prominence of positive brand associations towards both online grocery stores. Interviewees highlighted that customers appreciate good customer service, product quality, saving time, fast deliveries. All those advantages help to build the image of trustworthy brand. Both interviewees were happy to mention that the majority of customers after trying the service become loyal clients. They value loyal customers as they help to build brand awareness, by recommending this service to others. Word of mouth is a very powerful tool of communication and branding.

When interviewees were asked to distinguish their target customer, marketing manager from Barbora characterized their target customer as an inhabitant of Vilnius, Kaunas and Klaipėda regions, having average and higher than average income, open for innovations and price insensible. To be more specific, he described a target customer of Barbora as mother who finds it convenient to order groceries delivery and a young businessman who does not want to spend his precious time standing in line at the shop. Also, it is a business client. Marketing manager from LastMile stated that their target customer is an inhabitant of largest Lithuanian cities, open for innovations, price sensitive that values speed of delivery.

Both representatives of Lithuanian online grocery stores mentioned that their main goal is to help their customers to save precious time and offer good quality

service. Other possible dimensions of customer-based brand equity mentioned during the interviews were: positive brand associations; good customer service; product quality; fast deliveries; trustworthy brand; market influencer; word of mouth. The above mentioned 9 possible dimensions of customer-based brand equity for the online grocery stores extracted from the expert interviews are listed in Table 2 using a code EI (expert interview).

Customer survey. The quantitative survey with customers allowed to evaluate each possible customer-based brand equity dimension and their level of relevance for the customers of online grocery stores. Possible customer-based brand equity dimensions for the customers of online grocery stores that were provided for the evaluation during customer survey are listed in Table 2. After collection of customer responses, collected data was analysed and average meanings for dimension were calculated.

Table 2 summarizes the results from the customer survey providing average meanings for each evaluated dimension and the level of relevance. The maximum possible average meaning is 5 and such an evaluation indicates the highest relevance. Dimensions that are as close as possible to the average meaning of 5 (4.5–5) can be considered as very relevant customer-based brand equity dimensions for the online grocery stores. Average meanings between 3.5–4.4 are considered as relevant dimensions. And average meanings between 2.5–3.4 are considered as having average importance. Average meanings 2.4 and below are considered as having low relevance meaning; they should not be considered as dimensions that build customer-based brand equity for online grocery stores.

Results from the customer survey show that 31 dimensions out of 33 can be considered as valid dimensions of customer-based brand equity for online grocery stores. This conclusion is made due to the fact that 31 dimension received average meaning 2.5 and higher showing that almost all evaluated dimensions were either very relevant (4.5–5), relevant (3.5–4.4) or had average relevance (2.5–3.4). Results from customer survey indicated that customer-based brand equity of online grocery stores can be built based on 5 very relevant dimensions, 22 relevant dimensions and 4 dimensions that have average relevance.

Main drivers of customer-based brand equity for online grocery stores that proved to be very relevant are: saving time (4.8); good price (4.7); fresh products (4.6); quality of service (4.5); reputation of retail chain behind (4.5). Those 5 dimensions represent 5 different clusters of dimensions: customer focus, product quality, delivery amenities, financial benefits and brand.

Dimensions that have lower relevance, however are still important dimensions of customer-based brand

equity for online grocery stores, are 22 dimensions: value for money (4.4); fast delivery (4.4); customer experience (4.3); customer service (4.3); attractive offers and discounts (4.3); brand associations (4.3); trustworthy brand (4.2); free delivery (4.2); possibility to combine shops in one order (4.2); socially responsible brand (4.2); convenient app (4.1); wide product portfolio (4.1); brand awareness (4.1); market influencer (4.0); word-of-mouth (3.9); eco-friendly packaging (3.9); different payment methods (3.9); environmentally friendly solutions (3.8); high quality products (3.8); self-service food terminals (3.7); innovative solutions (3.6); waste reduction (3.6). All 22 dimensions represent all clusters of dimensions.

Four dimensions were proved as having average relevance for customer-based brand equity of online grocery stores: citizenship (3.3); new services (3.2); express delivery (within 1 h 30 min) (3.0); money returns from purchases, retail chain money (2.9). These dimensions can be considered as the aspects that online grocery stores should put less efforts if at all.

Dimensions that were confirmed as not relevant for building customer-based brand equity of online grocery stores were deliveries by independent couriers (citizens) (2.3) and collection of points (2.4). One of the mentioned dimensions - deliveries by independent couriers (citizens) – is considered as competitive advantage of one of the analysed online grocery stores. This suggests that one of the analysed online grocery stores should consider carefully if this dimension is worth the investment. However, if this dimension is used to save costs and strengthen other dimensions like fast delivery, customer experience, innovative solutions or others, then it is considered as reasonable.

Conclusions

1. Based on the analysis of scientific and practical literature, it is possible to conclude that a better understanding of customer-based brand equity is strategically important for online grocery stores. Consumer-based brand equity receives

a significant attention from the academic and business communities; however little is known about retailer customer-based brand equity. Current frameworks are too abstract for understanding the uniqueness of the retail industry and too simplistic to understand the interrelationships among the dimensions in the retailer brand equity building process. Existing customer-based equity frameworks are usually product-based and, consequently should not be used when it comes to conceptualizing the brand equity of retailers, because they fail to capture important dimensions that are unique to the retailing industry.

2. During the empirical research it was possible to determine relevant dimensions of customer-based brand equity for online grocery stores. Five most important dimensions that online grocery stores should focus most while building their customer-based brand equity are: saving time, good price (financial benefits cluster), fresh products (product quality cluster), quality of service (customer focus cluster), reputation of retail chain behind (brand cluster). Other 22 dimensions were proved to be relevant customer-based brand equity dimensions for online grocery stores. Four dimensions were proved as having average relevance (citizenship, new services, express delivery, money returns from purchases, retail chain money). Dimensions that were confirmed as not relevant are deliveries by independent couriers (delivery amenities cluster) and collection of points (financial benefits cluster). They should be excluded from variables list when building customer-based brand equity for online grocery stores.

3. Since the results of empirical research are representative and show what creates value for customers of online grocery stores, results from this empirical research could be applied widely when creating online shopping solutions for customers. Results could be used by existing and future online grocery stores. Results might be context specific, so the initial list of dimensions should be tested contextually.

References

- Aaker, D.A. (1991). *Managing brand equity: capitalizing on the value of a brand name*. New York: Free Press.
- Anselmsson, J., Burt, S., & Tunca, B. (2017). An integrated retailer image and brand equity model: Re-examining, extending, and restructuring retailer brand equity. *Journal of Retailing and Consumer Services*, 38, 194–203. DOI: 10.1016/j.jretconser.2017.06.007.
- Barbora official website (2020). Retrieved March 11, 2020, from <https://www.barbora.lt/?&subcat=8348220c-abdc-4dba-a97c-052e05d5b91c&SortBy=brand&&subcat=8348220c-abdc-4dba-a97c-052e05d5b91c&SortBy=brand>. (in Lithuanian).
- Budzinauskienė, E. (2018). *'Barbora' Vilniuje pastatė pirmuosius paštomatus ('Barbora' introduced first self-service food terminals in Vilnius)*. Retrieved March 11, 2020, from <https://www.delfi.lt/verslas/verslas/barbora-vilniuje-pastate-pirmuosius-maistomatus.d?id=79845553>. (in Lithuanian).

- Chatzipanagiotou, K., Christodoulides, G., & Veloutsou, C. (2019). Managing the consumer-based brand equity process: A cross-cultural perspective. *International Business Review*, 28, 328–343. DOI: 10.1016/j.ibusrev.2018.10.005.
- Chockevičiūtė, V. (2019). *Lietuvių startuolis meta iššūkį 'Barborai': pažadas prekes pristatyti per pusvalandį (Lithuanian startup challenges 'Barbora': promise to deliver in half an hour)*. Retrieved March 11, 2020, from <https://www.delfi.lt/verslas/verslas/lietuviu-startuolis-meta-issuki-barborai-pazadas-prekes-pristatyti-per-valanda.d?id=81819749>. (in Lithuanian).
- Cifci, S., Ekinci, Y., Whyatt, G., Japutra, A., Molinillo, S., & Siala, H. (2016). A cross validation of consumer-based brand equity models: driving customer equity in retail brands. *Journal of Business Research*, 69, 3740–3747. DOI: 10.1016/j.jbusres.2015.12.066.
- Deloitte (2019). *Global powers of retailing*. Retrieved March 9, 2020, from <https://www2.deloitte.com/content/dam/Deloitte/global/Documents/Consumer-Business/cons-global-powers-retailing-2019.pdf>.
- Juškauskaitė, V. (2019). *'Barboros' vienvaldystę sugriauti nebus lengva: šią prabangą gali sau leisti tik turintys gilią kišenes (It won't be easy to destroy 'Barbora' autocracy: this luxury can only be let in by those who have deep pockets)*. Retrieved March 11, 2020, from <https://www.delfi.lt/m360/naujausi-straipsniai/barboros-vienvaldyste-sugriauti-nebus-lengva-sia-prabanga-gali-sau-leisti-tik-turintys-gilias-kisenes.d?id=82623715>. (in Lithuanian).
- Keller, K.L., Aperia, T., & Georgson, M. (2012). *Strategic brand management*. London: Prentice Hall.
- M360 (2019, June). *Nuolatinis 'Barboros' Lietuvoje vadovas – A.Mikalasuskas (Permanent CEO of 'Barbora' in Lithuania is A.Mikalasuskas)*. Retrieved March 11, 2020, from <https://www.delfi.lt/m360/naujausi-straipsniai/nuolatinis-barboros-lietuvoje-vadovas-a-mikalasuskas.d?id=81352426>. (in Lithuanian).
- Mikoliūnaitė, K. (2019). *Konkurencija 'Barborai': maistą į namus užsisakyti galima ir iš 'Iki' (Competition to Barbora: food can be ordered from 'Iki' as well)*. Retrieved March 11, 2020, from <https://www.15min.lt/verslas/naujiena/bendroves/konkurencija-barborai-maista-i-namus-bus-galima-uzsisakyti-ir-is-iki-663-1218024>. (in Lithuanian).
- Nam, J., Ekinci, Y., & Whyatt, G. (2011). Brand equity, brand loyalty and consumer satisfaction. *Annals of Tourism Research*, 38(3), 1009–1030. DOI: 10.1016/j.annals.2011.01.015.
- Troiville, J., Hair, J.F., & Cliquet, G. (2019). Definition, conceptualization and measurement of customer-based retailer brand equity. *Journal of Retailing and Consumer Services*, 50, 73–84. DOI: 10.1016/j.jretconser.2019.04.022.
- Vizbarienė, R. (2019). *'Iki' pasiūlė užsisakyti prekių internetu ('Iki' offered order groceries online)*. Retrieved March 11, 2020, from <https://www.vz.lt/prekyba/2019/10/17/iki-pasiule-uzsisakyti-prekiu-internetu>. (in Lithuanian).

SURFACE MODELLING OF A UNIQUE HERITAGE OBJECT: USE OF UAV COMBINED WITH CAMERA AND LIDAR FOR MOUND INSPECTION

*Dainora Jankauskienė^{1,2}, Indrius Kuklys¹, Lina Kuklienė¹, Birutė Ruzgienė¹

¹Klaipėda State University of Applied Sciences, Lithuania

²Latvia University of Life Sciences and Technologies, Latvia

*Corresponding author's email: d.jankauskiene@kvk.lt

Abstract

Nowadays, the use of Unmanned Aerial Vehicle flying at a low altitude in conjunction with photogrammetric and LiDAR technologies allows to collect images of very high-resolution to generate dense points cloud and to simulate geospatial data of territories. The technology used in experimental research contains reconstruction of topography of surface with historical structure, observing the recreational infrastructure, obtaining geographic information for users who are involved in preservation and inspection of such unique cultural/ heritage object as are mounds in Lithuania. In order to get reliable aerial mapping products of preserved unique heritage object, such photogrammetric/ GIS procedures were performed: UAV flight for taking images with the camera; scanning surface by LiDAR simultaneously; processing of image data, 3D modelling and generation of orthophoto. Evaluation of images processing results shows that the accuracy of surface modelling by the use of UAV photogrammetry method satisfied requirements – mean RMSE equal to 0.031 m. The scanning surface by LiDAR from low altitude is advisable, relief representation of experimental area was obtained with mean accuracy up to 0.050 m. Aerial mapping by the use of UAV requires to specify appropriate ground sample distance (GSD) that is important for reducing number of images and time duration for modelling of area. Experiment shows that specified GSD of 1.7 cm is not reasonable, GSD size increased by 1.5 time would be applicable. The use of different software in addition for DSM visualization and analysis is redundant action.

Key words: UAV, LiDAR, photogrammetry, images acquisition, 3D modelling, mound survey, landscape, orthophoto.

Introduction

Mounds are a unique heritage objects of the history specifically asserted only to the Baltic culture. Lithuanian plains were neither good for hiding, nor for fighting back; therefore, ancestors used to dig and pour fortifications. The majority of these structures (mounds) dug thousands of years ago have remained until today. Approximately 850 mounds have remained in Lithuania. Everyone can visit these unique witnesses of the life and battles of the Baltic tribes, enjoying the view and feeling the Lithuanian history. The most beautiful mounds of Lithuania can be found using coordinates and maps (Lithuanian nature, 2020).

Unmanned Aerial Vehicle (UAV) is the platform flying at low altitude and with integrated camera, laser scanner can be successfully used for taking images and laser scanning of various territories/ surfaces. The technique of UAV-Photogrammetry is related with image data acquisition, processing and generation of the aerial mapping products used in cartographic or GIS environment. UAV-Photogrammetry is rapidly changing the classical methods used in surveying. UAV with mounted camera and flying at low distances above ground mostly has advantages for collecting images of the linear objects, cultural monuments, etc. (Černiauskas & Bručas, 2014; Haala *et al.*, 2011; Ruzgienė *et al.*, 2015).

Aerial mapping is one of the most popular methods for obtaining 3D information about the surface and other objects using images. The quality of images and aerial mapping products mainly depends on success

of aerial photography mission, qualified guidance of photogrammetric workflow, appropriate development of aerial mapping requirements. UAV mission has to be executed in good meteorological conditions – light wind (1.6–3.3 m s⁻¹) and minimal cloudiness. (Ruzgienė *et al.*, 2017; Eisenbeiss, 2009; Neitzel *et al.*, 2011; Linder, 2009).

Light Detection and Ranging (LiDAR) is up-to-date remote sensing technology that is related with laser pulses used for construction of high-resolution digital surfaces. Generated from LiDAR data (point clouds) elevation models are applied for various applications, especially in GIS environment. The innovations implemented by LiDAR manufacturers allow to lower the costs and size of surface models. Exploitation of a LiDAR system mounted onto a UAV as a 3D mapping device is a new approach and can be easily used by everybody. LiDAR can determine positions, velocity and other characteristics by analyzing pulsed laser light reflected from an object's surface. This gives a 3D model of terrain topography, represents relief, etc., so that a ground surveyor can easily use it (Kothe & Bock, 2009; Aksamitauskas *et al.*, 2016).

With the use of unmanned aerial system, producing point clouds from a low altitude, the system is more unstable in the air; therefore, the improvement of the data accuracy by eliminating misalignment and positional inaccuracies caused by a bad trajectory plays an important role in the LiDAR data processing workflow (Kraus, 2007; Ruzgienė, 2008).

The goal of research is to detect the effective technique for accurate aerial mapping of surface with

historical structure as are mounds in order to preserve such the unique object, capturing and modelling the situation in real time, observing the recreational infrastructure.

Materials and Methods

The relevance and objective of investigations is to find out the effective technology for mapping, visualization and inspection of cultural heritage objects. The aim of the long-term culture strategy is to preserve and update the cultural identity of Lithuania, which unites common European cultural values, to ensure its continuity, open access and competitiveness in the contemporary cultural diversity of the European Union. Up-to-date aerial cartography techniques, LiDAR and GIS, provide the products of area topography opening up cultural values of protected unique objects for the public and allowing them to be accessed remotely.

The use of Unmanned Aerial Vehicle in conjunction with technical means (cameras, laser scanner, GPNS) for mapping of various objects leads to a new standard of surveying technology. Such aerial imaging solution is designed for the reduction of time and cost, collecting the aerial mapping data as well as guarantees the reliability of product. The company Dà-Jiāng Innovations (DJI), China, rapidly turns to a new standard in mapping of territories combining a robust and highly user-friendly system. The standard technical means from DJI company used for surface mapping: the unmanned aerial vehicle *MATRICE 600 PRO* with possibility of integration of camera *Zenmuse X5*, thermal camera *ZENMUSE XT*, laser scanner *MAPPER LITE 2*, GPNS, etc. (Dji Enterprise, 2020).

The UAV *MATRICE 600 PRO* can operate all day long and can be used for everyone who requires the product of high accuracy working efficiently. Through one UAV flight a large number of images can be collected and point cloud can be gathered from laser scanning of specified territory. The integrated at UAV camera is equipped by the imaging sensor that captures sharp and color-rich images. The DJI aerial imaging application operates the *MATRICE 600 PRO* and can be ready to fly in approx. 6 min. The *MATRICE 600 PRO* climbs in a straight line until the required flight height is reached, navigation will start towards the flight area waypoints. Maximal roll angle is 45°. During UAV take-offs, the risk elements should be clarified, e.g., obstacles, wind speed, etc.

The image data processing software *Pix4Dmapper* developed at Computer Vision Lab in Switzerland is the main tool for application of modern technologies with the use of UAV. *Pix4Dmapper* software is supplied with computer-vision algorithms combined with

proven state-of-the-art photogrammetric techniques to produce outputs with the highest accuracy and with minimal manual interaction. This software is a new concept extending the stereo view triangulation and increasing the accuracy of 3D modelling. Aerial images are imported in consideration with their locations, orientations, and camera calibration parameters. The use of photogrammetric algorithms allows correction of the image orientations. The software at first performs the adjustment with photo tie points, automatically matching the tie points in all images. Tie points are usually distributed densely, even in a low terrain texture. *Pix4Dmapper* software has efficient possibility for orthophoto generation, surface modelling, etc. Operations with this package are fully automated and flexible, data input is scalable, output data are easily editable and on-site quality assessment is instant (Pix4D, 2020).

Using different platforms and sensors for capturing the images, the main photogrammetric procedures remain as follows: aerial triangulation, image orientation, generation of point cloud for surface modelling, producing of orthophoto map and vector data collection for GIS or cartographic needs. The relation between images and object coordinates can be established, when the coordinates of ground control points are determined using classical surveying technologies measured by GPS or total stations (McGlone, 2004; Rock *et al.*, 2011; Nurminen *et al.*, 2013).

MicroStation is a CAD software platform for two and three dimensional design and drafting, developed and sold by Bentley Systems and used in the architectural and engineering industries. It generates 2D/3D vector graphics objects and elements and includes building information modeling (BIM) features. MicroStation is used in the engineering and architecture fields; however, it has evolved through its various versions to include advanced modeling and rendering features. It can provide specialized environments for architecture, civil engineering, mapping, or plant design, etc. (Bentley, 2020).

The software package *TerraScan* and *TerraMatch*, *Terrasolid*, Finland is designed for managing and processing of LiDAR point clouds collected by the use of UAV platform as well. *TerraScan* is software for LiDAR data handling and 3D vector data designing. *TerraMatch* is a tool for improving the accuracy and quality of the raw laser points cloud (TerraScan & TerraMatch, 2020).

In order to get reliable and effective geographic information about preserved unique object/terrain with topography of historical structure, the photogrammetric/ GIS workflow was developed as follows:

- UAV flight for taking images with the high-resolution camera.

- Scanning surface by LiDAR during the UAV flight simultaneously.
- Image data processing: generation of point cloud, 3D model and orthophoto.
- Surface modelling from LiDAR data.
- Analysis and evaluation of experimental results.

Experiment: study area, technical means, data acquisition and processing

The study area – Medvėgalis mound (Figure 1) has been selected optionally, regarding the most significant object for the landscape monitoring and preservation of landscape architecture in the historical aspect (Medvėgalis, 2020).



Figure 1. Study area: the mound of Medvėgalis, Lithuania.

The mound of Medvėgalis located on the western part of Lithuania (recreational area of regional park) in accordance with sociological survey is the most popular landscape for recreation and observation of nature. The condition of recreational infrastructure is satisfactory. Medvėgalis is a 30–50 m high, medium-steep hill with elevated part (234.5 m above sea level) with two flat terraces on the southern and western slopes.

Data acquisition was carried out using the following technical means: an unmanned aerial vehicle (UAV) of model *MATRICE 600 PRO*, DJI with a mounted camera *Zenmuse X5*, 3D laser scanner *MAPPER LITE 2* (Figure 2). The *MATRICE 600 PRO* is low cost and weight platform. The weight is 9.5 kg, max. speed – 65 km h⁻¹, hovering time – 32 min, flying height – up to 2500 m. Main features of gimbal camera DJI *Zenmuse X5* are: sensor's size – 17.3×13.0 mm, resolution – 4608×3456 px. (16 M), focal length – 15 mm (Matrice 600 Pro, Zenmuse X5, 2020).

Simultaneously with image data acquisition, surface was scanned by 3D LiDAR system *MAPPER LITE 2*: weight – up to 2.2 kg, automatic operation – up to 1 hr., navigation systems are *GPS*, *GLONASS*, *Beidou*, *Galileo1*, *SBAS*.



Figure 2. UAV with equipped gimbal camera, laser scanner, GPNS used for photogrammetric data collection of study area.

Before UAV flight for taking images, 7 ground control points (GCPs) were well distributed and marked on the territory by standard marks/ targets of size 40×40 cm. The coordinates of the targets were determined by the GPS in LKS94 coordinate system using *LitPOS* network with an accuracy of 5–8 cm. Such a created photogrammetric network needs the external orientation of images.

For planning of UAV flight over experimental area software *Litchi hub* was used. Average ground sample distance (GSD) of size 1.7 cm was specified considering required accuracy of aerial mapping production. The flight height (aerial ground level) was fixed at a 70 m.

The flight mission was executed over the object of about ~12 ha area. Parallel flight strips are of length – 5.9 km, distance between strips – 50 m (Figure 3). The mission of aerial photography lasts – 17 min.



Figure 3. UAV flight mission: flight strips over experimental area.

Image processing was performed by the use of digital photogrammetric software *Pix4Dmapper*.

Accuracy of images' exterior orientation – mean RMSE 3.1 cm. Initial processing of 436 images takes 1.5 hours. Generated an orthophoto map and three-dimensional model is presented in Figure 4.

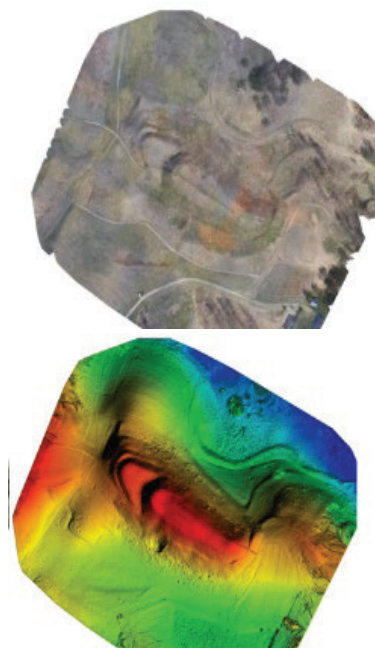


Figure 4. Aerial mapping products: orthophoto map and DSM of an experimental area.

LiDAR data (dense point cloud), acquired after scanning surface by laser scanner *MAPPER LITE 2* integrated in UAV, was processed using software *MicroStation, Bentley*. This software is an innovative and integral technology of today providing possibilities for 3D surface modelling. Constructed 3D elevation model by the use of *Bentley MicroStation* is presented in Figure 5.

3D modelling has been generated step by step, measuring and evaluating of matching results that shows accuracy of height points. After repeated generation of 3D model, it performs a find match. This tool analyzes

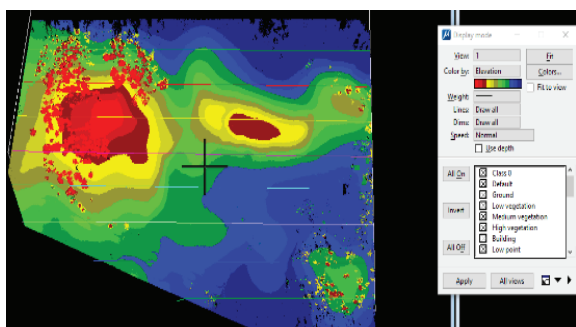


Figure 5. Digital elevation model constructed from LiDAR data: colors selected for terrain relief classification – the highest area is colored in red and the lowest area is blue.

the laser data mismatch and resolves the correction parameters using a surface matching technique. After performing this function, 3 discrepancies in the laser data were detected and corrected.

Results and Discussion

Geo-information technologies allow to create 3D digital surface models, using image or LiDAR data acquired from UAV mission and greatly facilitate human work. Such models are the main information source for preservation of cultural heritage as are mounds, providing an opportunity to analyze the area and its terrain even after many years.

UAV flight height above the ground level depends on the size of the image pixel on the area, the camera sensor size and focal length. The resolution of images (GSD) describes the accuracy of photogrammetric products and can be calculated (Ruzgienė *et al.*, 2015):

$$GSD = p \frac{H}{c}, \quad (1)$$

where, p is the pixel size of the sensor, μm ; H (AGL) – aerial ground level, m; c – camera focal length, mm.

The verified information from experimental/study area of mound Medvėgalis images processing outputs contains: average Ground Sampling Distance (GSD) – 1.7 cm, dataset with 436 images, camera optimization – 2.7% relative differences between initial camera parameters (is below 5%), georeferencing accuracy – the mean RMS error of the 7 GCPs (3D) measurement is 0.031 m (is below than $3 \times \text{GSD}$)

The following rule (criteria) is applied for the accuracy evaluation of aerial mapping products: maximum errors of planimetric coordinates should be higher than $1.0 \times \text{GSD}$ and $1.6 \times \text{GSD}$; elevations $-2.5 \times \text{GSD}$.

Relief representation obtained from the dense points cloud gives valuable information for users evaluating and inspecting the surface with historical

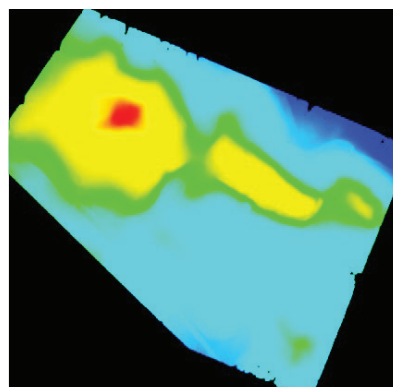


Figure 6. 3D surface model constructed by the use of software *GeoMap*.

structure. For such a terrain, a DEM obtained from the point cloud derived from LiDAR data, accuracy is 8 cm after first step of point matching; after the next stage, the mean error decreased to 5 cm.

In addition, using popular software in surveying *GeoMap* 3D model has been constructed for raster data visualization (Figure 6).

The software *GeoMap* allows to analyze raster images in conjunction with the exact location of all objects and surfaces by associating a geographic location with GPS coordinates. Figure 6 shows a developed digital 3D surface model, which depicts only the points on the ground surface, without other ground details. The different colors show the relief classification and are chosen according to the terrain: the highest areas are painted in red; the lowest place is blue.

Conclusions

1. The technique used in experimental research contains objective to be efficient for reconstruction of topography of terrain surface with historical structure, observing the recreational infrastructure, obtaining reliable 3D data and geographic information for users who are involved in preservation inspection of such a unique cultural object as are mounds in Lithuania.
2. Experiment in the Medvėgalis mound (Lithuania) is based on collecting images during the UAV flights, simultaneously scanned by LiDAR too. Such a selected technique shows priority when

applying classical surveying technologies and instruments, such as GPS, terrestrial laser scanner or total stations significantly reducing the time costs for field works in the territory, i.e., the mission of aerial photography over the area of 12 ha, taking images and simultaneously scanning territory with laser scanner lasts only about 20 min, while processing of 436 images takes 1.5 hours.

3. Analysis and evaluation of image processing results (generating aerial mapping products) show that the accuracy of surface modelling by the use of UAV photogrammetry method satisfied requirements: mean RMSE equal to 0,031 m, when required accuracy of images exterior orientation is $3 \times \text{GSD}$, i.e., 0.057 m.
4. The scanning surface by LiDAR from low altitude is advisable. Usually the spatial model generated from LiDAR data is more accurate in Z direction. Relief representation of experimental area, when DEM was generated from point cloud, the mean accuracy was obtained up to 0.050 m.
5. Therefore, aerial mapping by the use of UAV photogrammetry method, specified GSD size is important reducing the number of images and time for processing. Experiment shows, that specified GSD of 1.7 cm is not reasonable, recommendation is to increase GSD size by 1.5 time, while reference network is created with accuracy of about 7 cm.
6. The additional use of other software (for example, *GeoMap*) for DSM visualization and analysis is a redundant action.

References

- Aksamitauskas, V.Č., Kriauciūnaitė-Neklejonovienė, V., Rekus, D., Ruzgienė, B., Puodžiukas, V., & Stanionis, A. (2016). Advantages of laser scanning systems for topographical surveys in roads engineering. *The Baltic Journal of Road and Bridge Engineering*. ISSN 1822-427X / eISSN 1822-4288. Vol. 11(2), pp. 153–159.
- Bentley Micro Station. Retrieved March 4, 2020, from <https://www.bentley.com/en/products/brands/microstation>.
- Dji Enterprise. How LiDAR is Revolutionizing Mapping and Geospatial Data. Retrieved January 2, 2020, from <https://enterprise.dji.com/news/detail/how-lidar-is-revolutionizing-mapping-and-geospatial-data>.
- Černiauskas, E., & Bručas, D. (2014). Daugiasraigčių sraigtaspanių naudojimo stebėjimo užduotims atlikti tyrimas. *Aviacijos technologijos* (Aviation technologies). 2(1), 53–58 (in Lithuanian).
- Eisenbeiss, H. (2009). *UAV photogrammetry*: Dissertation, Federal Institute of Technology (ETH), Institute of Geodesy and Photogrammetry, Zurich, Switzerland, Mitteilungen. 235 p.
- Haala, N., Cramer, M., Weimer, F., & Trittler, M. (2011). Performance Test on UAV-Based Photogrammetric Data Collection, *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences* 38-1/C22: 7–12. DOI: 10.5194/isprsarchives-XXXVIII-1-C22-7-2011.
- Kothe, R., & Bock, M. (2009). Preprocessing of Digital Elevation Models – derived from Laser Scanning and Radar Interferometry – for Terrain Analysis in Geosciences, Switzerland.
- Kraus, K. (2007). *Photogrammetry: Geometry from Images and Laser Scans*. Berlin: Walter de Gruyter. 459 p.
- Linder, W. (2009). *Digital Photogrammetry. A practical Course*. Springer-Verlag, Berlin, Heidelberg. 33–73, pp. 121–131.
- Lithuanian nature. Retrieved March 3, 2020, from <http://lietuvosgamta.lt>.
- Manual of Photogrammetry* (Edited by J. Chris McGlone). (2004). American Society for Photogrammetry and Remote Sensing, Maryland, USA. pp. 959–963.

- Matrice 600 pro. Retrieved March 2, 2020, from <https://www.dji.com/lt/matrice600-pro>.
- Medvėgalis. Retrieved February 22, 2020, from https://www.piliakalniai.lt/piliakalnis.php?piliakalnis_id=535.
- Neitzel, F., & Klonowski, J. (2011). Mobile Mapping with Low-Cost UAV System. *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences* 38-1/C22: 1–6.
- Nurminen, K., Karjalainen, M., Yu, X., Hyypä, J., & Honkavaara, E. (2013). Performance of dense digital surface models based on image matching in the estimation of plot-level forest variables. *ISPRS Journal of photogrammetry and Remote Sensing*, Vol. 83, pp.104–115.
- Pi4D. Retrieved January 10, 2020, from <http://pix4d.com/>.
- Rock, G., Ries, J.B., & Udelhoven, T. (2011). Sensitivity Analysis of UAV-Photogrammetry for Creating Digital Elevation Models (DEM). *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences* 38-1/C22: 1–5.
- Ruzgienė, B. (2008). *Fotogrametrija*. Vilnius: Technika. pp. 93–132.
- Ruzgienė, B., Berteška, T., Gečytė, S., Jakubauskienė, E., & Aksamitauskas, V.Č. (2015). The surface modelling based on UAV Photogrammetry and qualitative estimation. *Measurement*. Oxford: Elsevier Ltd. Vol. 73, pp. 619–627.
- Ruzgienė, B., Aksamitauskas, V.Č., Daugėla, I., Prokopimas, Š., Puodžiukas, V., & Rekus, D. (2015). UAV photogrammetry for road surface modelling. *The Baltic journal of road and bridge engineering*. Vilnius: Technika. ISSN 1822-427X. Vol. 10, No. 2, pp. 151–158.
- Ruzgienė, B., Kuklienė, L., Jankauskienė, D., Kuklys, I., & Vrubliauskienė, R. (2017). Fotogrametria reikalavimai, keliami aerokartografavimui: UAV-Fotogrametrija. *Inžinerinės ir edukacinės technologijos* (Engineering and educational technologies). Kauno technikos kolegija. ISSN 2029-9303. Nr. 2, pp. 21–28.
- TerraScan – Software for LiDAR Data Processing and 3D Vector Data Creation. Retrieved January 25, 2020, from <http://www.terrasolid.com/products/terrascanpage.php/>.
- TerraMatch – Calibration and Strip Adjustment. Retrieved January 15, 2020, from <http://www.terrasolid.com/products/terramatchpage.php/>.
- Zenmuse X5. Retrieved February 5, 2020, from <https://www.dji.com/lt/zenmuse-x5s>.

THE CHANGE OF NATURAL LANDSCAPE IN LITHUANIA

*Giedrė Ivavičiūtė

Vytautas Magnus University, Lithuania

Kaunas Forestry and Environmental Engineering University of Applied Sciences, Lithuania

Klaipėda State University of Applied Sciences, Lithuania

*Corresponding author's email: ivavice@gmail.com

Abstract

The purpose of this article is to carry out an analysis of the natural landscape of the Republic of Lithuania in 2004–2019. During the preparation of the article, the following scientific methods were used: literature analysis, determination and evaluation of the current situation, grouping method, comparison method, graphical method, analytical and statistical analysis methods, logical analysis.

The article analyzes the change of the area of natural (natural, subnatural) landscape components (natural forests, wetlands, water bodies) during the period between the years 2004 and 2019.

The analysis showed that the two components of the natural landscape of the Republic of Lithuania during 2004–2019 increased: the forest area (132,849.03 ha or 6.15%) and water bodies (3,668.49 ha or 1.38%). Unfortunately, the area of wetlands has decreased by 50,990.20 ha (35.05%).

During the analyzed period, the natural landscape of Lithuania increased by 85527.97 ha or 3.39%.

At present, it is particularly important to care for and restore valuable landscape complexes to fulfill their ecosystem functions. One of the most important challenges is to reconcile urbanization and nature conservation so as not to reduce significant areas of the country's natural landscape.

Key words: natural landscape, components, change of landscape.

Introduction

Landscape proposes a complex of shaping and understanding environments and landscapes (Steiner, 2011).

A harmonious landscape is a normative conception. It admits that landscape functions are the basis for solution to difficulty of human welfare.

The long-lasting landscape is surrounded in the context of regional or local landscapes. The resolution to adjust the use of a district landscape may have effects for the coherence of landscape (Opdam *et al.*, 2018).

Landscape is seen as a fast-moving combination between cultural and natural environment. It is the aspect of coherent people viewpoints towards occupied land. Landscape has a distinctive history, which is part of their sameness (Antrop, 2000).

A regional landscape is a compound ecological and social system consisting of a fast-moving mosaic of land use.

Management demands a comprehension of the reacting human and natural processes working on the landscape over a continuity of spatial and secular scales (Parrot & Meyer, 2012).

Currently, about 50% of the earth's ice – free land has been rearranged, and fundamentally all land has been influenced by climate change, integrated landscapes, etc. (Turner II, Lambin & Reenberg, 2007).

Land-use change shoves biodiversity into human changed landscapes, where local ecosystems are enclosed by human induced land covers. As a result of land – use change, a rising number of species is being 'made' to occupy human – changed landscapes, which are mosaic of various land covers (Galan-Acedo *et al.*, 2019).

Analysis of land use change has been a prevalent method concentrating on specific difficulties involved with human – environment collaboration including changes of land – use activity and land cover (for example, deforestation), reactions to climate change and effects of diverse environmental changes on forestry, agriculture, ecosystem functioning, etc. (Robinson & Carson, 2013).

Article relevance. Landscape specialists apply an integrative outlook to comprehend various natural and human – caused drivers of landscape change acting meantime and interactively, frequently focused on connected natural systems and human (Mayer *et al.*, 2016).

Exceptional changes to worldwide ecological systems have led to paying attention to practical methods to maintain the ecological sustainability of a speedily changing Earth (Raymond & Cleary, 2013).

The biggest difficulty of landscape ecology in the coming years will be to force sustainability science and design to enhance education and development innovativeness about culture of landscapes and ecology, the fundamental of landscape sustainability (Musacchio, 2011).

Knowing how landscape aspects influence biodiversity models and ecological procedures at landscape and local scales is critical for extenuating consequences of worldwide environmental change (Tshamtke *et al.*, 2012).

The object of article is the natural landscape of Lithuania.

The aim is to carry out a research of the changes in the natural landscape of Lithuania during the years 2004–2019.

Tasks to be resolved:

1. To characterize the present state of the natural landscape of Lithuania.
2. To research the components of natural landscape of the Republic of Lithuania and their changes.
3. To investigate the changes of natural landscape area in the Republic of Lithuania during the years 2004–2019.

Materials and Methods

Analytical, statistical, logical and comparative analysis methods were used for the investigation.

In order to determine the change of the natural landscape area, the data of the Land Fund of the Republic of Lithuania for 2004–2019 was analyzed.

During the research, the current situation of the Lithuanian natural landscape was analyzed. The condition of the components of the natural landscape is presented.

The clustering method was used in this article. Lithuania's natural landscape is divided into natural components: forests, water bodies and wetlands.

The paper deals with the change of the area of these components between the years 2004–2019. Changes in the natural landscape area over a period of 15 years were also analyzed.

The method of logical analysis was used to determine the causes of the changes of landscape components as well as the changes in the natural landscape.

The land fund statistics of Lithuania, graphically shown in figures, were used for the implementation of the analysis of natural landscape change of the Republic of Lithuania during the years 2004–2019. Statistics were analyzed, processed and presented in 10 figures.

Also, there is foreign and Lithuanian literature and research analysis presented in scientific publications or journals.

Results and Discussion*Research of the present status.*

Natural (natural, subnatural) landscape is a landscape formed and still under the influence of natural processes, for the development of which natural processes have an essential influence, and human activities have a minimal influence (relatively natural forests, wetlands, water bodies preserved) (Lietuvos, 2004).

The landscape of Lithuania is a mosaic territorial and spatial structure created by the natural factors that have occurred since the last glacial period and the human economic activity that started 4–5 thousand years ago. Analyzing the natural features of the Lithuanian landscape (Basalykas, 2014), it was found

that the country is dominated by clayey plains (55.2% of the territory).

Lithuania is dominated by rustic landscape (covers about 75% of Lithuania territory). Larger areas of the natural landscape are preserved in the eastern and southeastern part of the country, in the western part of the Samogitian Heights, in the areas of the great deltas and do not exceed 15% of the territory of Lithuania. About 10% of the territory is occupied by a rapidly expanding urban, urbanized landscape.

In Lithuania, natural frame areas cover about 60–65% of the country's area. This corresponds to a geologically optimal proportion between areas that are heavily used and nature-sustaining.

The share of natural frame areas in individual municipalities varies, for example, in Joniškis, Pakruojis, Pasvalys municipalities it is 35–40%, Varėna, Zarasai – up to 75–80% of their total area. Most of the district municipalities have 55 to 65% of their area covered by natural frame. The ecological optimization of natural frame areas is inevitably linked to the increase of the total forest cover of the country.

Protected territories are an important part of the natural landscape; therefore, these protected areas so important for the landscape and the environment have been established in Lithuania for the preservation of nature and values. There are 6 state parks in the country, which cover 0.29% of Lithuania, 514 reserves, occupying 2.42%, and 684 state protected natural heritage objects. There are 3 restoration sites in the country, 35 state parks, which make up 9.08% of the country's territory, 32 biosphere polygons (3.62%) and 566 Natura 2000 sites (1.94%).

The high level of modern anthropogenic impact on nature in terms of farmland uptake, urbanization, environmental pollution, nature recreation and other economic and non-economic interventions threatens the maintenance of any natural ecosystem.

The landscape must be shaped as a whole, i.e. as a natural and urban complex where the balance between the natural, anthropogenic and anthropogenic landscape is very important.

Changes in the components of the natural landscape.

The natural landscape consists of the following natural components: forests, water bodies and wetlands.

Forests. In Lithuania forest area covers 33.07%. As stated by the data of 2019, forest area covers 2,158,949.68 ha.

After examination of the present status of the forests in Lithuania, it has been confirmed that the forested counties are Alytus (48.28%), Vilnius (42.91%) and Telšiai (35.83%) (Figure 1).

It has been established that the least forested is Marijampolė county (21.50%).

In Lithuania, coniferous species make up 56.20%, pine forests predominate here (35.40%) (Figure 2) (Ivavičiūtė, 2018).

In 2004, forests covered an area of 2,026,100.00 ha in the country. Between 2004–2019 the forest area increased by 132,849.03 ha (6.15%) (Figure 3).

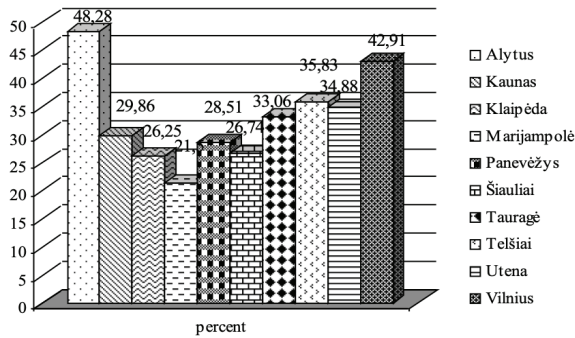


Figure 1. Forest coverage in counties in percentages in 2019.

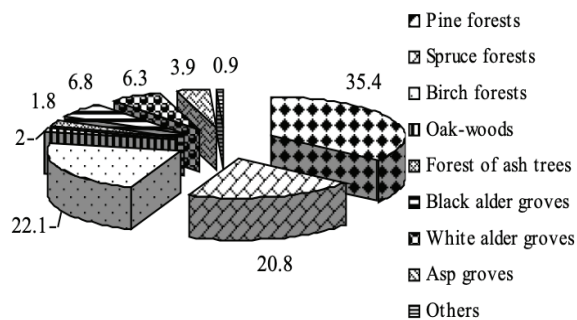


Figure 2. The main types of forest trees in percentage.

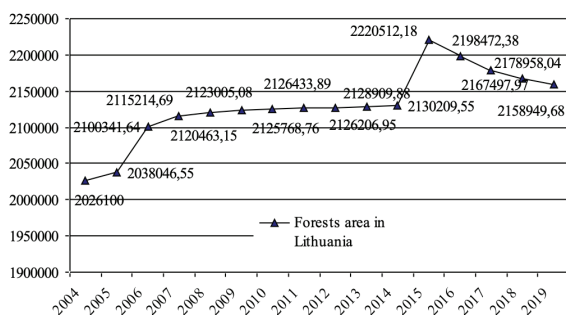


Figure 3. Forest area change in Lithuania in 2004–2019 (Nacionaline, 2004–2019).

It was determined that the forest area in Lithuania during the years 2004–2019 increased from 32.03% to 33.07% (Figure 4).

The forest area has developed due to the enforcement of the forest development program, the stimulation of planting forests, the stimulation of forests' reclamation, participation in the Rural Development Program and etc.

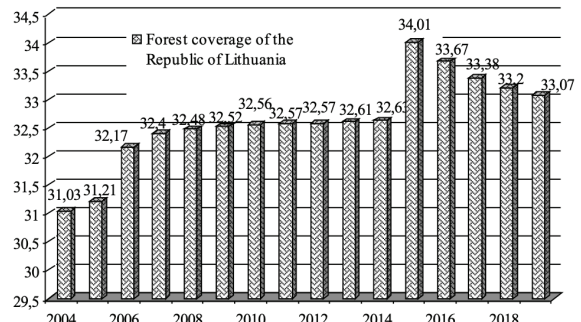


Figure 4. Forests coverage in percentages in Lithuania during the years 2004–2019 (Nacionaline, 2004–2019).

Water bodies. The entire territory of Lithuania is located in the Baltic Sea basin. The country's hydrographic network consists of rivers, channels, lakes and ponds, the coast, the Baltic Sea and artificial impassable surface water bodies (Figure 5).

According to the data of February 2018 registration of cadastral objects of rivers, lakes and ponds of Lithuania, the largest area of the territory of country is covered by lakes – 884.56 km², Curonian Lagoon covers 413 km², riverbeds cover 332 km² and ponds – 236 km².

There are 5 channels registered in Lithuania: King Wilhelm Channel, Venta overpass, Sanžilė Channel, Merkys – Vokė Channel, Pailiai Channel with a total length of 55,845 km.



Figure 5. Map of Lithuanian Hydrographic Network (Aplinkos, 2019).

There are 2756 lakes in the country with a total area of 88456,491 ha. Of these, 31 are larger than 500 ha and 10 are larger than 1000 ha. Lithuania has 150 lakes larger than 100 ha, estimating for 65% of the lake area. The largest number of lakes is in the Baltic highlands (the lakes in Zarasai area reach 10%), the smallest number – in the Central Lithuanian lowlands. There are 1034 ponds registered in the cadastre of rivers, lakes and ponds. Their total area is 23619,395 ha,

of which more than 500 ha – 4 and more than 1000 ha – 3. The largest lakes of the country are: Tauragnas (62.5 m), Malkėstaitis (57.0 m) and Asveja (50.2 m).

Lithuania has around 30000 streams and rivers, which are longer than 0.25 km and their absolute length is 63.70 thousand km. The number of streams and rivers, which are longer than 3 km is 4418. The number of rivers longer than 10 km is 816 (3%), and more than 100 km – 17. The longest rivers in the country are Nemunas (475 km in Lithuania), Neris (234 km).

Administrative units for river basin districts are formed for the management of Lithuanian waters and water bodies: Nemunas, Venta, Lielupė and Dauguva.

In 2004, water bodies made up 4.01% of the total area of Lithuania and occupied 262,199.77 ha.

In 2019, water bodies made up 4.07% of the country territory.

The largest area of water bodies is found in Klaipėda county (54,784.49 ha), where water bodies make up 10.49% of the total area of the county. Water bodies are also abundant in Utena county (54026.25 ha or 7.51%) (Figure 6).

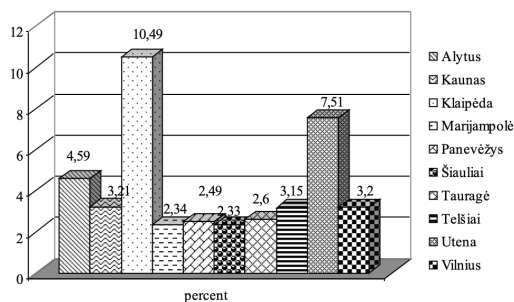


Figure 6. Water bodies coverage in counties of Lithuania in percentages in 2019.

During the interval of the years 2004–2019, the area of water bodies increased by 3,668.49 ha (1.38%) and by 2019 occupied 265,868.26 ha (Figure 7).

The area of water bodies increased during the analyzed time due to the development of new or existing ponds for fishing and other purposes.

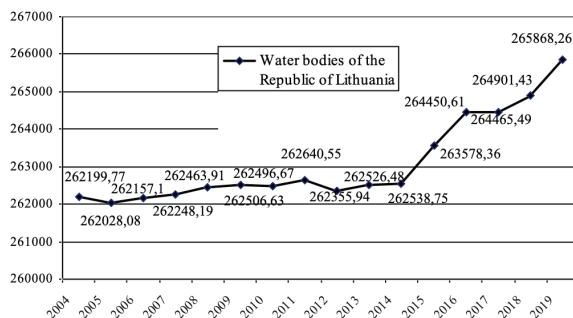


Figure 7. Water bodies change in the country between the years 2004–2019 (Nacionaline, 2004–2019).

At present, it is necessary to ensure that water bodies do not contain dangerous substances, watercourses are protected against erosion, the stability of water bodies and their coastal ecosystems is enhanced, and the coastal natural landscape and its aesthetic values are protected.

Wetlands – consistently wet areas of the earth’s surface with peculiar vegetation that results in the formation of peat.

Most of Lithuania’s wetlands are of lake origin. There are three types of wetlands in Lithuania: low moors, transitional moors and bogs. Most of Lithuania is dominated by low moors. They make up 71% of all wetland area. Bogs occupy 22%, while transitional moors – 7%. The Great Low Moors of Lithuania formed in the valleys of the Merkys and Vokė Rivers – Baltoji Vokė, Naujienos, Šakos wetlands. Small marshes are common in Eastern Lithuania.

Seven Lithuanian sites have been assigned as Wetlands of International Importance: Čepkeliai, Kamanai, Viešvilė Nature Reserve and Žuvintas Biosphere Reserve, as well as Nemunas Delta Regional Park, Girutiškis Wetland and Adutiškis – Svyla – Birvėtai Wetlands Complex.

Analysis of wetlands in Lithuanian counties revealed that the majority of wetlands are situated in Alytus County, where wetlands make up 2.97%, Utena (2.65%) and Vilnius (1.97%) counties (Figure 8).

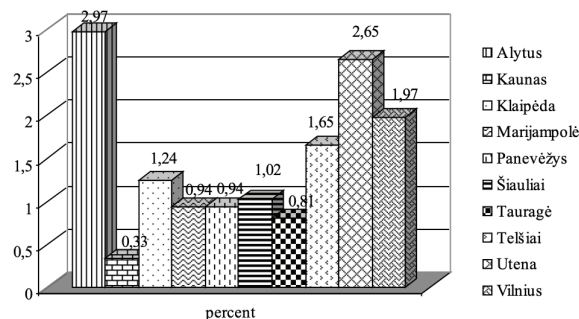


Figure 8. Wetlands area in Lithuanian counties in percentages in 2019.

Most wetlands are located in Molėtai (6.55% of municipal area), Zarasai (5.79%) and Ignalina (4.63%) districts. The Nemunas Delta, the Seaside Lowland are also waterlogged.

Pakruojis (2.10%), Pasvalys (1.29%), and Šakiai (1.28%) areas are among the least waterlogged.

In Lithuania, wetlands made up 2.23% of country and covered 145,477.45 ha in 2004.

In 2019, wetlands made up 1.45% of the country territory.

The area of wetlands in 2004–2019 decreased by 50,990.20 ha (35.05%) and covered 94,487.25 ha in 2019 (Figure 9).

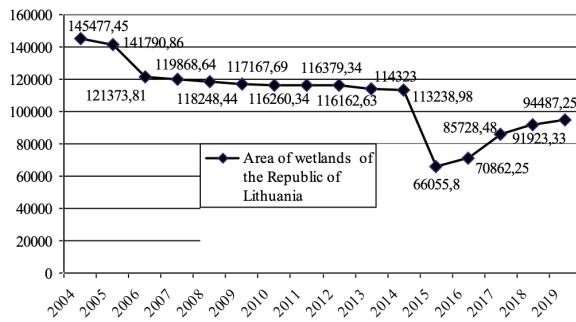


Figure 9. Wetlands area change in the country in 2004–2019 (Nacionaline, 2004–2019).

The wetland area was shrinking due to natural processes, climate change and human activities.

For humanity, understanding the key functions of wetlands, it is crucial to ensure that the use of wetlands for one’s own purposes does not disturb the balance of nature, and thus the ability to survive or meet other needs.

The change of natural landscape.

The analysis shows that the components of the natural landscape of the Republic of Lithuania have changed. It has been figured out that during 2004–2019 the forest area increased by 132,849.03 ha or 6.15%, water bodies increased by 3,668.49 ha or 1.38%. Unfortunately, the area of wetlands in Lithuania decreased by 50,990.20 ha (35.05%).

In 2019, wetlands made up the smallest part of the natural landscape (3.75%), but forests (85.70%) and water bodies (10.55%) made up the largest part (Figure 10).

In 2004, the natural landscape of the country covered 37.27% of the total area of Lithuania and occupied 2,433,777.22 ha. In 2019, the natural landscape made up 38.59%.

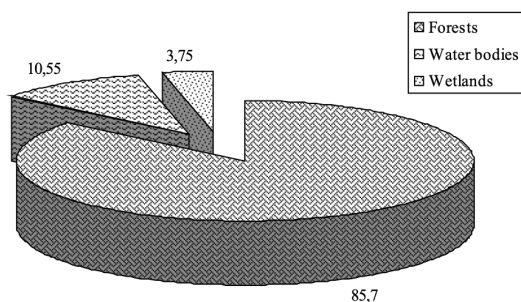


Figure 10. Percentage distribution of components of the natural landscape in 2019.

References

Antrop, M. (2000). Geography and landscape science. *Belgeo*. 1(2): 9–36. DOI: 10.4000/belgeo.13975.
 Aplinkos apsaugos agentūra. (2019). Lietuvos Respublikos upių, ežerų ir tvenkinių kadastras. (The Environmental Protection Agency. Cadastre of Rivers, Lakes and Ponds of the Republic of Lithuania).

In 2004–2019, the natural landscape of Lithuania increased by 85527.97 ha or 3.39% (Figure 11).

The increase of the natural landscape of Lithuania was impacted by the progress of the forest area (6.15%).

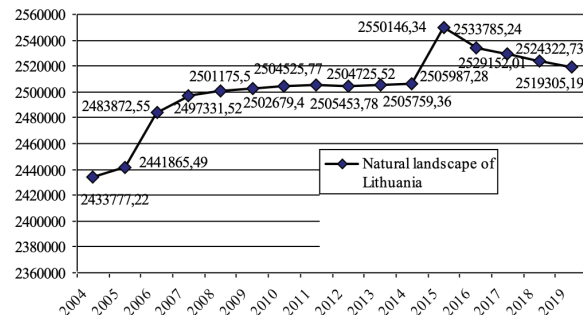


Figure 11. Natural landscape change in Lithuania in 2004–2019 (Nacionaline, 2004–2019).

We need to save and protect natural resources and this important movement includes forests, water, land, and biological species.

The natural landscapes are essential for clean water, healthy ecosystems, climate resilience, cultural heritage, outdoor recreation, and local sense of place. Benefits like improved water quality, increase in biodiversity and habitat protection, and reductions in greenhouse gases, are all inherent in the strategy that protects and preserves land.

Conclusions

1. Lithuania is dominated by rustic landscape (75% of Lithuania). Larger areas of the natural landscape are preserved in the eastern and southeastern parts of the country, in the western part of the Samogitian Heights, in the areas of the great deltas and do not exceed 15% of the territory of Lithuania. About 10% of the territory is occupied by a rapidly expanding urban, urbanized landscape.
2. Between 2004–2019 the forest area of the country increased by 132,849.03 ha (6.15%).
3. During the years 2004–2019, the area of water bodies enlarged by 3,668.49 ha (1.38%) and by 2019 occupied 265,868.26 ha.
4. The area of wetlands in 2004–2019 decreased by 50,990.20 ha (35.05%) and in 2019 covered 94,487.25 ha.
5. In 2004–2019, the natural landscape of Lithuania increased by 85527.97 ha or 3.39%. The increase of the natural landscape of Lithuania was impacted by the progress of the forest area.

- Retrieved January 15, 2020, from <http://vanduo.gamta.lt/cms/index?rubricId=7cdeb451-1844-4e9d-af55-af1be4215e83>. (in Lithuanian).
- Basalykas, A. (2014). Lietuvos kraštovaizdis. (The Lithuanian Landscape). Vilnius, 243 p. (in Lithuanian).
- Galan-Acedo, C., Arroyo-Rodriguez, V., Andresen, E., Arregoitia, L.V., Vega, E., Peres, C.A., & Ewers, R.M. (2019). The conservation value of human-modified landscapes for the world's primates. *Nature Communications*. 10, Article No. 152.
- Ivavičiūtė, G. (2018). The Change of Forest and Its Area in Lithuania // *Research for rural development 2018: annual 24th international scientific conference proceedings* / Latvia University of Agriculture. Jelgava. ISSN 1691-4031. Vol. 1, pp. 174-180.
- Lietuvos Respublikos Vyriausybės nutarimas. *Dėl Lietuvos Respublikos kraštovaizdžio politikos krypčių aprašo patvirtinimo*. (Resolution of the Government of the Republic of Lithuania. *On Approving the Description of the Landscape Policies of the Republic of Lithuania*). (2004 12 01, No. 1526. From the State News: 2004, No. 174-6443; valid summary 2014 01 31). (in Lithuanian).
- Mayer, A., Buma, B., Davis, A., Gagne, S.A., Loudermilk, L., Scheller, R.M., Schmiegelow, F.K.A., Wiersma, Y.F., & Franklin, J. (2016). How Landscape Ecology Informs Global Land-Change Science and Policy. *BioScience*. Vol. 66, Issue 6, pp. 458-469. DOI: 10.1093/biosci/biw035.
- Musacchio, L.R. (2011). The grand Challenge to operationalize landscape sustainability and the design-in-science paradigm. *Landscape Ecology*. 26, 1-5.
- Nacionalinė žemės tarnyba prie Žemės ūkio ministerijos. (2004-2019). *Lietuvos Respublikos žemės fondas*. (The National Land Service under the Ministry of Agriculture. *Land Fund of the Republic of Lithuania*). Vilnius. 2004-2019, 144 p. (in Lithuanian).
- Opdam, P., Luque, S., Nassauer, J., Verburg, P.H., & Wu, J. (2018). How can landscape ecology contribute to sustainability science? *Landscape Ecology*. 33, 1-7.
- Parrott, L., & Meyer, W.S. (2012). Future landscapes: managing within complexity. *Frontiers in Ecology and the Environment*. DOI: 10.1890/110082.
- Raymond, C.H.M., & Cleary, J. (2013). A Tool and Process that Facilitate Community Capacity Building and Social Learning for Natural Resource Management. *Ecology and Society*. 18 (1), 25. DOI: 10.5751/ES-05238-180125.
- Robinson, G.M., & Carson, D.A. (2013). Applying landscape science to natural resource management. *Ecology and Society* 18 (1), 32. DOI: 10.5751/ES-05639-180132.
- Steiner, F. (2011). Landscape ecological urbanism: Origins and trajectories. *Landscape and Urban Planning*. Vol. 100, Issue 4. pp. 333-337.
- Tscharntke, T., Tylianakis, J.M., Rand, T.A., Didham, R.K., Fharing, L., Batary, P., Bengtsson, J., Clough, Y., Crist, T.O., Dormann, C.F., Ewers, R.M., Frund, J., Holt, R.D., Holzschuh, A., Klein, A.M., Kleijn, D., Kremen, C., Landis, D.A., Laurance, W., Lindenmayer, D., Scherber, Ch., Sodhi, N., Steffan-Dewenter, I., Thies, C., van der Putten, W.H., & Westphal, C. (2012). Landscape moderation of biodiversity patterns and processes – eight hypotheses. *Biological Reviews*. DOI: 10.1111/j.1469-185X.2011.00216.x.
- Turner II, B.L., Lambin, E.F., & Reenberg, A. (2007). The emergence of land change science for global environmental change and sustainability. *PNAS*. 104 (52). pp. 20666-20671. DOI: 10.1073/pnas.0704119104.

CLAY MINERALS AND HUMIC SUBSTANCES AS LANDFILL CLOSURE COVERING MATERIAL CONSTITUENTS: FIRST STUDIES

*Juris Burlakovs¹, Jovita Pilecka², Inga Grinfelde², Ruta Ozola-Davidane¹

¹University of Latvia, Latvia

²Latvia University of Life Sciences and Technologies, Latvia

*Corresponding author's email: juris@geo-it.lv

Abstract

Soil and groundwater as the leachate may contaminate surrounding watersheds, thus different pollutants from closed dumps and landfills pose significant risks to human health and ecology. Pollution may lead to soil and water degradation however it might be diminished through sustainable dump site closure projects and processual management. Several decades of clays and clay minerals studies lead to modified clay composites concept that is one of the potential promising solutions for building the landfill covering material and serve as capping biocover layer at the same time. As humic substances are constituents of soil organic matter, pollutants can be sorbed on the surfaces of complex molecules. This kind of humic acid-clay mineral composite materials thus might become as low cost building material component - covering material. Construction of such layer are to be performed as a combination of clay-humic composites and landfill mined fine fraction of waste with small amendment of natural soil. Several hypotheses that are already proven has to be mentioned: a) Clay minerals produce composites with humic substances; 2) Clay-humic complexes reduce through sorption both organic and inorganic pollutants; 3) Low risk of toxic byproducts from landfill mined waste fine fraction can be the problem; 4) Such composites mostly would trap toxic contaminants (e.g., pharmaceuticals) found in reworked fine fraction of waste.

The aim of the work is to provide alternative solution for landfill closure by giving theoretical considerations from multidisciplinary knowledge of environmental engineering, chemistry and waste management.

Key words: landfill biocover, solid waste fine fraction, leaching, circular economy.

Introduction

The landfills are systems with pollution and aftercare period that takes a long time. Increasing amount of household and industrial wastes, and landfilling in a business-as-usual way lead to a large number of contaminated sites that are called landfills (Burlakovs *et al.*, 2013; Critto *et al.*, 2006; Prokop, Schamann, & Edelgaard, 2000). This environmental contamination as a result of anthropogenic activities have direct and indirect toxic effects in an unacceptable amount and concentrations that are known from historical studies and monitoring; however, it should be periodically updated for the use of territorial planning or in case of a change of the land use (Burlakovs, Kasparinskis, & Klavins, 2012). A special attention should be paid to this pollution in a former dump sites, as in many cases this is most problematic for remediation and situated nearby cities. Priority aspect of the importance to be remediated and re-cultivated in an innovative way is tremendously necessary (Burlakovs, 2014; Burlakovs, 2017; Hogland, 2018).

The aim of the work is to provide alternative solution for landfill closure by giving theoretical considerations from multidisciplinary knowledge of environmental engineering, chemistry and waste management.

Former landfills with mixed household waste can be composed of hazardous waste as well as all other types of waste. Historically all around the world different kinds of municipal, residential and construction waste plus hazardous substances were buried in these places; decades of dumping left

unacceptable locations of concentrated threat to environment and human health (Burlakovs, 2008, 2012). Innovative solutions and closure, treatment of such dump sites is of high importance.

Humic substances (HS) is of the most important groups of biomolecules (Stevenson, 1982) and has own unique chemical category. HS has distinct unique properties, and those might be isolated from the organic mass. The most common definition is that 'HS are a general category of naturally occurring, biogenic, heterogenous organic substances that can generally be characterized as being yellow to black in color, of high molecular weight and refractory' (Stevenson, 1994).

Soil remediation at dumps often needs more complicated solution starting from primitive soil excavating and transporting to other waste landfills up to sophisticated techniques of remediation by vitrification and using additives that can be used for the treatment of soil.

Remediation with HS has shown good result for diminishing the content of biologically available copper and lead. Contaminated sandy soils and sandy loam from Ap and E soil horizons transformed metals to biologically unavailable stable form and the result was diminished amount of free exchange cations (Burlakovs & Vircavs, 2011; Burlakovs *et al.*, 2013).

Clay components and humic acids treatment performed to contaminated soil with heavy metals as model contaminants has been done previously. Remediation with easily available additive materials of natural origin such as clays found all over the world in large amounts and modified with HS might be a

good solution. HS alone performed good results on treatment of copper (Burlakovs *et al.*, 2016).

Remediation technologies can be divided into: *in-situ* and *ex-situ* methods (Reddy, Adams, & Richardson, 1999). Soil amendments is *in-situ* technology for the revitalization process of polluted soil. Clays and clay minerals and humic acids (HA) are important remediation agents for the immobilization of metals in soils (Dercova *et al.*, 2007; Indianara *et al.*, 2009). Thus, locally available resources as natural clays and organic substances are important in this technology and may be effectively used for the treatment. After general treatment enhanced phytoremediation is welcome to finish the process with environmentally and circular economy friendly solution (Valujeva *et al.*, 2018).

Materials and Methods

Metal complexation and its potential in remedial processes

Clays are alkaline porous alumio-silicates (Joshi *et al.*, 2002), negatively charged (Mohamed, 2001), neutralized with cations in the structure sites itself

(Breck, 1974; Mondales, Carland, & Aplan, 1995). Clay minerals with soil organic matter are of particular interest due to ability to form stable complexes with metal ions (Havelcava *et al.*, 2009).

Metal ion complex formation with its natural ability of metal complexation is of unexplored potential for landfill coverage in future. The strength of the interaction among organic ligands and metals may be modeled as a function of pH and reactant concentration (Byrne *et al.*, 2011) and experimentally proves usefulness of natural clays and HS as remediation amendment for contaminated soils in dumps.

Metals in the Ap horizon during the time of 4 months have been bound in more stable complexes than at the beginning before the HS amendment – a stable fraction has increased for both Cu and Pb. Already the original soil of Ap horizon has high content of organic matter and adding the HS is increasing the stability of metal complexes even further (Figure 1) ((Burlakovs *et al.*, 2013).

Recalculation of metal ions in the solution as well as the ability of metals to bind with humic acids and clays are calculated according formulas (1) and (2):

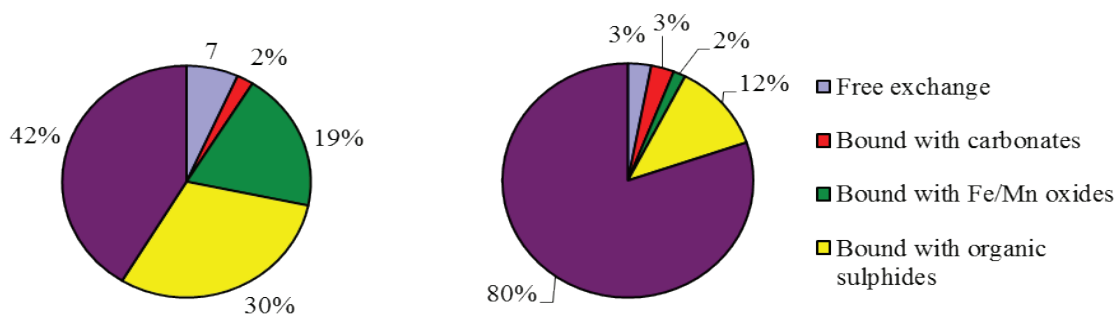


Figure 1. Illustrative example of enhanced copper stability (a) Forms of copper in sandy loam soil with no amendments of HS; (b) Forms of copper sandy loam soil with HS solution amendment of 20 g l⁻¹. (Burlakovs *et al.*, 2013).

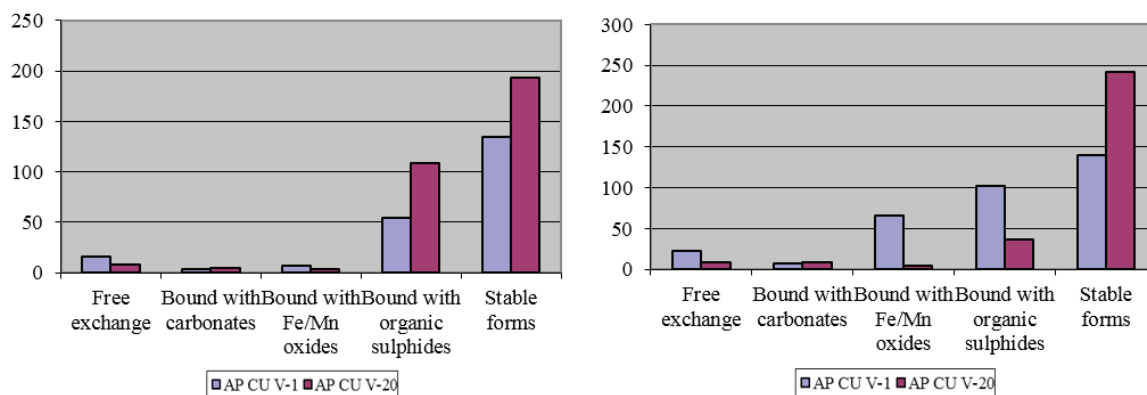


Figure 2. Illustrative example for HS amendment enhanced Pb and Cu stabilization in complexes (a) Amount of free exchange lead (Pb) in sandy soil with no amendment and HS solution of 20 g l⁻¹; (b) Amount of free exchange copper (Cu) in sandy soil with no amendment and HS solution of 20 g l⁻¹.

$$Cu + HS = CuHS \quad (1),$$

where the Cu is the amount of Cu^{2+} moles in solution and HS – amount of moles of humic acid in the solution, and

$$K_o = \frac{CuHS}{[Cu] \cdot (HS - CuHS)} \quad (2),$$

where [Cu] – concentration of hydrated Cu^{2+} in the solution; K_o – stability constant of complex forming; CuHS – amount of moles, which are included in complexes (Bresnahan, Grant, & Weber, 1978).

It is absolutely clear that clay minerals and HS have done significant enhanced stabilization of Pb and Cu in the Ap horizon of sandy soil – it is in biologically less available forms, adding HS is improving formation of stable metal complexes less available for plants. Series of experiments by using HS have shown promising results for diminishing the content of biologically available Cu and Pb, so we may assume that those ingredients might be of good use for using in landfill closure to stop the migration of heavy metal pollution (Figure 2) (Burlakovs *et al.*, 2013). Contaminated soil exposed to HS transform metals to biologically less available forms meaning that HS can be added in order to make biocover with the use of clay-humic substances composites in biocover material.

Results and Discussions

Clay minerals and HS composites for pharmaceutical treatment

Natural clay minerals as potential sorbents have received a lot of attention, due to low cost,

abundance and interesting properties relevant to treatment procedures of contaminants (Zhang *et al.*, 2015). Innovative sorbents may be synthesized by various modification opportunities (Lee & Tiwari, 2012). For organic pollutants sorption mainly organoclays were popular studied subject (Ozola *et al.*, 2019). Intercalation of various organic compounds is processed in interlayers of double clay layers (Yariv & Cross, 2002). With some given examples like kaolinite processed in modification with hexadecyltrimethylammonium bromide, may be used to treat chromates, arsenate and nitrates (Li & Bowman, 2001), while some multi-layered clay minerals with organic modification were good for pesticide removal (Rodríguez-Cruz *et al.*, 2007). The problem is that modified organoclays often may have side effects and are hazardous to environment *per se* (Jemeljanova, Ozola, & Klavins, 2019; Sarkar *et al.*, 2013).

Conversely, humic acid is a non-toxic, naturally occurring organic matter which results from long-term physical, microbial and chemical transformations of organic debris and can be used for clay modification to obtain a sorbent for the removal of organic and inorganic pollutants (Jin *et al.*, 2016; Wang *et al.*, 2018). Humic acid is a chemically heterogeneous compound which contains both hydrophilic and hydrophobic molecules with numerous functional groups – for example, hydroxyl and carboxyl, phenolic and amino groups. Humic acid is mostly negatively charged due to deprotonation of the phenolic and carboxyl groups in aqueous solutions where environment is from weakly acidic to basic (Anirudhan, Suchithra, & Radhakrishnan, 2009; El-Sayed *et al.*, 2019). Figure 3

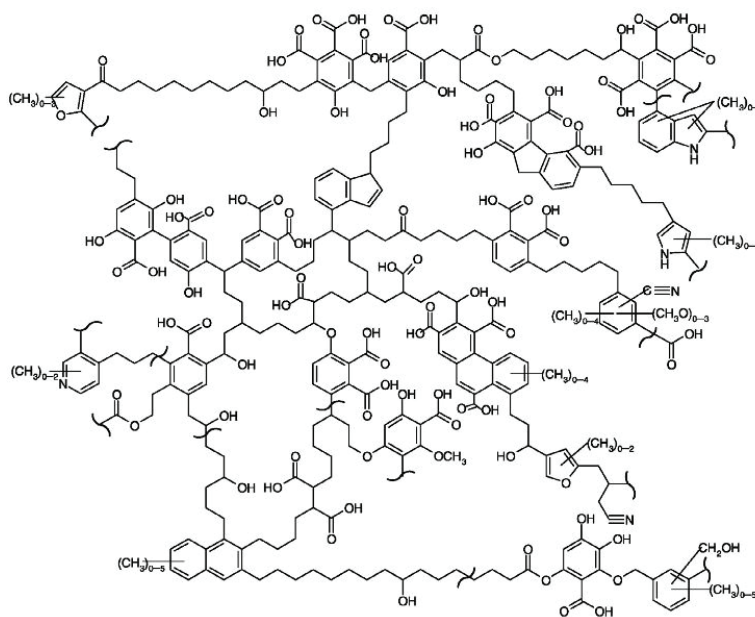


Figure 3. Humic acid structure (Zhu *et al.*, 2018).

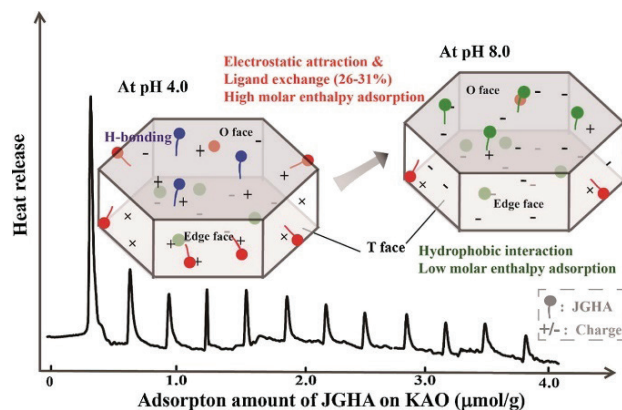


Figure 4. The thermogram and indication of humic acid adsorption sites on kaolinite surface (Chen *et al.*, 2017).

shows the hypothetical structure of humic acid containing all structural components.

Sorption mechanism of humic acid on clay mineral surface includes ligand exchange, cation and water bridging, entropy driven hydrophobic interactions and van der Waals interactions (Chotzen *et al.*, 2016; Feng, A.J. Simpson, & M.J. Simpson, 2005; Wang *et al.*, 2018). The favourable sorption mechanisms are determined by the nature of humic acid molecules as well as by the properties of the clay mineral surface. Humic acid adsorption on kaolinite mineral mostly occurs by ligand exchange reaction between polar organic functional groups of humic acid and hydroxyl edge surface sites of clay mineral. While humic acid adsorption on smectite type minerals occurs mostly on the large basal surfaces; electrostatic interaction, bridging and hydrogen bonding account for the formation of organic coatings on the clay particles (Chotzen *et al.*, 2016; Feng, A.J. Simpson, & M.J. Simpson, 2005; Ghosh 2009; Wang *et al.*, 2018).

Also, an important factor that affects adsorption is pH of environment (Figure 4). For example, at alkaline pH hydrophobic attraction is the main interaction mechanism between humic acid and kaolinite. This reaction mainly occurs only on the kaolinite's hydrophobic basal plane (T-face). At acidic pH the edge-face and the O-face of kaolinite becomes more positively charged and electrostatic interaction between clay mineral and humic acid is one of main adsorption mechanisms next to ligand exchange (Chen *et al.*, 2017).

There have been numerous publications studying clay minerals and humic acid composites for removal of different pollutants such as heavy metals (Jin *et al.*, 2016), radioactive elements (Hongxia *et al.*, 2016) and dyes (Anirudhan, Suchithra, & Radhakrishnan, 2009) and phosphorus in wastewater and surface waters (Zamparas *et al.*, 2015).

However, currently crucial is contamination with pharmaceutical products – emerging environmental

pollutants widely used as human and veterinary drugs to treat infectious diseases. These chemicals have gained increasing attention in recent years, due to increasing consumption of pharmaceuticals and continuous release into the aquatic environment. Pharmaceuticals enter the water systems through wastewater effluent, sewage sludge, landfill leachate, manure applications or from industries. The main problem is that removal of these compounds during wastewater treatment is presently insufficient, resulting in their occurrence not only in treated wastewater but also in ground water and drinking water. The effect and the fate of pharmaceuticals on the human health and wildlife are still unclear. Though, it has been found these compounds potential to cause aquatic toxicity, genotoxicity, endocrine disruption and development of resistance in pathogenic microbes (Couto, Lange, & Amaral, 2019; de Oliveira *et al.*, 2019; Dogan *et al.*, 2020; Dordio *et al.*, 2017; Stadlmair *et al.*, 2018).

Recent studies have shown that clay minerals and clay-humic acid composites can be natural, low cost and effective sorbents to remove various pharmaceutical products from environment. For example, montmorillonite has been used to remove pharmaceutical products such as tramadol and doxepine (Thiebault, Guegan, & Boussafir, 2015); kaolinite to remove ofloxacin (Li, Bi, & Chen, 2017); and natural clay (mainly consisting from smectite and kaolinite) to remove ibuprofen, naproxen and carbamazepine from aqueous solutions (Khazri *et al.*, 2017). While montmorillonite and humic acid composites have been studied as sorbents for removal of tetracycline, oxytetracycline and chlortetracycline which are broad spectrum antibiotics widely used in animal production. Results confirmed that the sorption of antibiotics significantly increased by the presence of humic acid coating on the clay mineral surface. And adsorption of all antibiotics on montmorillonite-humic acid composite was due to existence of coordination or protonation (or both) between cations of clay and

oxygen in tetracyclines (Bansal, 2012). Likewise, modification of kaolinite with humic acid significantly improved sorption capacity of carbamazepine and increased pore volume and specific surface area of composite material (Wang *et al.*, 2018). However, there have been studies confirming that raw clay and humic acid are more effective sorbents alone than clay and humic acid composite materials due to absence of sorption sites that are being occupied by humic acid molecules (Pils & Laird, 2007; Yan, Hu, & Jing, 2012).

Conclusions

The landfill closure process has similarities with environmental remediation process; however, there are additional components related whether the capping of contamination includes the need of sorption, such as water of irrigation or leachate recirculation and total produced leachate treatment with innovative materials. Environmental risks related to failed closure of

landfills require strong scientific basis of geochemical processes in immobilizing matrix and about pollutants. Innovative closure of landfills by capping with landfill mined fine fraction material mixed with modified clay with humic substances is one of prospective solutions. More studies are needed and modelling elaborated in order to find the right recipe for finding the best constituents to stop leaching of pollution out of the landfill as well as mitigate greenhouse gas emissions through methane degradation.

Acknowledgements

This study was supported by Project 1.1.1.2/VIAA/3/19/531 'Innovative technologies for stabilization of landfills – diminishing environmental impact and resources potential in frames of circular economy' and EU ESF Project Nr.8.2.2.0/18/A/010 'Academic Staff Renewal and Continuing Professional Development at the University of Latvia'.

References

- Anirudhan, T.S., Suchithra, P.S., & Radhakrishnan, P.G. (2009). Synthesis and characterization of humic acid immobilized-polymer/bentonite composites and their ability to adsorb basic dyes from aqueous solutions. *Applied Clay Science*, 43(3-4), 336–342. DOI: 10.1016/j.clay.2008.09.015.
- Bansal, O.P. (2012). Thermodynamics of equilibrium adsorption of antibiotics by clay minerals and humic acid-clay complexes. *National Academy Science Letters*, 35(2), 109–114. DOI: 10.1007/s40009-012-0028-8.
- Breck, D.W. (1974). *Zeolite molecular sieves: structure, chemistry and use*. New York, Wiley.
- Bresnahan, W.T., Grant, C.L., & Weber, J.H. (1978). Stability constants for the complexation of copper II ions with water and soil fulvic acids measured by an ion selective electrode. *Anal. Chem.*, 50 (12), 1675–1679. DOI: 10.1021/ac50034a026.
- Burlakovs, J. (2008). Groundwater sampling for monitoring purposes: Case studies in Latvia. In: Proc. International Multidisciplinary Scientific GeoConference SGEM 2012. Vol. 1. Proc. International Multidisciplinary Scientific GeoConference SGEM 2008 (pp. 687–690).
- Burlakovs, J. (2012). Dumps in Latvia: Preliminary research and remediation. In: Proc. International Multidisciplinary Scientific GeoConference SGEM 2012. Vol. 2. Proc. International Multidisciplinary Scientific GeoConference SGEM 2012 (pp. 55–62).
- Burlakovs, J., Janovskis, R., Stankevica, K., Hassan, I., & Lacis, S. (2014). Removal of heavy metals from contaminated soils by electrokinetic remediation. *Research for Rural Development*, 2, 122–126.
- Burlakovs, J., Kaczala, F., Stapkevica, M., Rudovica, V., Orupõld, K., Vincevica-Gaile, Z., Bhatnagar, A., Kriipsalu, M., Hogland, M., Hogland, W., & Klavins, M. (2016). Mobility of metals and valorization of sorted fine fraction of waste after landfill excavation. *Waste & Biomass Valorization*, 7, 593–602. DOI: 10.1007/s12649-016-9478-4.
- Burlakovs, J., Kasparinskis, R., & Klavins, M. (2012). Leaching of contamination from stabilization/solidification remediated soils of different texture. *Environmental & Climate Technologies*, 9 (1), 12–16. DOI: 10.2478/v10145-012-0011-0.
- Burlakovs, J., Klavins, M., Osinska, L., & Purmalis, O. (2013). The impact of humic substances as remediation agents to the speciation forms of metals in soil. *APCBEE Procedia*, 5, 192–196. DOI: 10.1016/j.apcbee.2013.05.034.
- Burlakovs, J., Kriipsalu, M., Arina, D., Kaczala, F., Shmarin, S., Denafas, G., & Hogland, W. (2013). Former dump sites and the landfill mining perspectives in Baltic countries and Sweden: GeoConference on Science and Technologies In Geology, Exploration and Mining, SGEM2013. Vol. 1. Proc. International Multidisciplinary Scientific GeoConference SGEM 2013 (pp. 485–492).
- Burlakovs, J., Kriipsalu, M., Klavins, M., Bhatnagar, A., Vincevica-Gaile, Z., Stenis, J., Jani, Y., Mykhaylenko, V., Denafas, G., Turkadze, T., Hogland, M., Rudovica, V., Kaczala, F., Møller Rosendal, R., & Hogland, W. (2017). Paradigms on landfill mining: from dump site scavenging to ecosystem services revitalization. *Resources, Conservation & Recycling*, 123, 73–84. DOI: 10.1016/j.resconrec.2016.07.007.

- Burlakovs, J., & Vircavs, M. (2011). Possible applications of soil remediation technologies in Latvia. *Environmental & Climate Technologies*, 13 (7), 46–53. DOI: 10.2478/v10145-011-0027-x.
- Byrne, L.A., Hynes, M.J., Connolly, C.D., & Murphy, R.A. (2011). Analytical determination of apparent stability constants using a copper ion selective electrode. *Journal of Inorganic Biochemistry*, 105 (12), 1656–1661. DOI: 10.1016/j.jinorgbio.2011.07.016.
- Chen, H., Koopal, L.K., Xiong, J., Avena, M., & Tan, W. (2017). Mechanisms of soil humic acid adsorption onto montmorillonite and kaolinite. *Journal of Colloid and Interface Science*, 504, 457–467. DOI: 10.1016/j.jcis.2017.05.078.
- Chotzen, R.A., Polubesova, T., Chefetz, B., & Mishael, Y.G. (2016). Adsorption of soil-derived humic acid by seven clay minerals: A systematic study. *Clays and Clay Minerals*, 64(5), 628–638. DOI: 10.1346/CCMN.2016.064027.
- Couto, C.F., Lange, L.C., & Amaral, M.C.S. (2019). Occurrence, fate and removal of pharmaceutically active compounds (PhACs) in water and wastewater treatment plants – A review. *Journal of Water Process Engineering*, 32, 100927. DOI: 10.1016/j.jwpe.2019.100927.
- Critto, A., Cantarella, L., Carlon, C., Giove, S., Petrzelli, G., & Marcomini, A. (2006). Decision Support-Oriented Selection of Remediation Technologies to Rehabilitate Contaminated Sites. *Integrated Environmental Assessment and Management*, 2 (3), 273–285. DOI: 10.1897/1551-3793(2006)2[273:DS SORT]2.0.CO;2.
- de Oliveira, M., Frihling, B.E.F., Velasques, J., Filho, F.J.C.M., Cavalheri, P.S., & Migliolo L. (2020). Pharmaceuticals residues and xenobiotics contaminants: Occurrence, analytical techniques and sustainable alternatives for wastewater treatment. *Science of The Total Environment*, 705, 135568. DOI: 10.1016/j.scitotenv.2019.135568.
- Dercova, K., Sejakova, Z., Skokanova, M., Baranciková, G., & Makovnikova, J. (2007). Bioremediation of soil contaminated with pentachlorophenol using humic acids bound on zeolite. *Chemosphere*, 66 (5), 783–790. DOI: 10.1016/j.chemosphere.2006.06.061.
- Dogan, A., Płotka-Wasyłka J., Kempieńska-Kupczyk, D., Namieśnik, J., & Kot-Wasik, A. (2020). Detection, identification and determination of chiral pharmaceutical residues in wastewater: Problems and challenges. *TrAC Trends in Analytical Chemistry*, 122. DOI: 10.1016/j.trac.2019.115710.
- Dordio, A.V., Miranda, S., Prates Ramalho, J.P., & Carvalho, A.J.P. (2017). Mechanisms of removal of three widespread pharmaceuticals by two clay materials. *Journal of Hazardous Materials*, 323, 575–583. DOI: 10.1016/j.jhazmat.2016.05.091.
- El-Sayed, M.E.A., Khalaf, M.M.R., Gibson, D., & Rice, J.A. (2019). Assessment of clay mineral selectivity for adsorption of aliphatic/aromatic humic acid fraction. *Chemical Geology*, 511, 21–27. DOI: 10.1016/j.chemgeo.2019.02.034.
- Feng, X., Simpson, A.J., & Simpson, M.J. (2005). Chemical and mineralogical controls on humic acid sorption to clay mineral surfaces. *Organic Geochemistry*, 36(11), 1553–1566. DOI: 10.1016/j.orggeochem.2005.06.008.
- Ghosh, S., Wang, Z.Y., Kang, S., Bhowmik, P.C., & Xing, B.S. (2009). Sorption and Fractionation of a Peat Derived Humic Acid by Kaolinite, Montmorillonite, and Goethite. *Pedosphere*, 19 (1), 21–30. DOI: 10.1016/S1002-0160(08)60080-6.
- Havelcava, M., Mizera, J., Sýkorová, I., & Pekař, M. (2009). Sorption of metal ions on lignite and the derived humic substances. *J. Hazard. Mater.* 161 (1), 559–564. DOI: 10.1016/j.jhazmat.2008.03.136.
- Hogland, M., Arina, D., Kriipsalu, M., Jani, Y., Kaczala, F., Salomão, A.L., Orupöld, K., Pehme, K.M., Rudovica, V., Denafas, G., Burlakovs, J., Vincevica-Gaile, Z., & Hogland, W. (2018). Remarks on four novel landfill mining case studies in Estonia and Sweden. *Journal of Material Cycles & Waste Management*, 20 (2), 1355–1363. DOI: 10.1007/s10163-017-0683-4.
- Hongxia, Z., Xiaoyun, W., Honghong, L., Tianshe, T., & Wangsuo, W. (2016). Adsorption behavior of Th(IV) onto illite: Effect of contact time, pH value, ionic strength, humic acid and temperature. *Applied Clay Science*, 127–128, 35–43. DOI: 10.1016/j.clay.2016.03.038.
- Indianara, C.O., Maria, A.S.D.B., Edson, A.S., Joao, H.D., Pedro, A.A., & Osxaldo, C.M.L. (2009). A comparative study for the ion exchange of Fe(III) and Zn(II) on zeolite NaY. *J. Hazard. Mater.*, 161 (2-3), 1404–1412. DOI: 10.1016/j.jhazmat.2008.04.111.
- Jemeljanova, M., Ozola, R., & Klavins, M. (2019). Physical-chemical properties and possible applications of clay minerals and humic acid composite materials. *Agronomy Research*, 17(S1), 1023–1032. DOI: 10.15159/AR.19.019.

- Jin, X., Zheng, M., Sarkar, B., Naidu, R., & Chen, Z. (2016). Characterization of bentonite modified with humic acid for the removal of Cu (II) and 2,4-dichlorophenol from aqueous solution. *Applied Clay Science*, 134, 89–94. DOI: 10.1016/j.clay.2016.09.036.
- Joshi, U.D., Joshi, P.N., Tamhankar, S.S., Joshi, V.P., Idage, B.B., Joshi, V.V., & Shiraljar, V.P. (2002). Influence of the size of extra framework monovalent cations in X-types zeolite on their thermal behaviour. *Thermochim. Acta*, 387 (2), 121–130. DOI: 10.1016/S0040-6031(01)00840-1.
- Khazri, H., Ghorbel-Abid, I., Kalfat, R., & Trabelsi-Ayadi, M. (2017). Removal of ibuprofen, naproxen and carbamazepine in aqueous solution onto natural clay: equilibrium, kinetics, and thermodynamic study. *Appl Water Sci.*, 7, 3031–3040. DOI: 10.1007/s13201-016-0414-3.
- Lee, S.M., & Tiwari, D. (2012). Organo and inorgano-organo-modified clays in the remediation of aqueous solutions: An overview. *Applied Clay Science*, 59–60, 84–102. DOI: 10.1016/j.clay.2012.02.006.
- Li, Y., Bi, E., & Chen, H. (2017). Sorption Behavior of Ofloxacin to Kaolinite: Effects of pH, Ionic Strength, and Cu(II). *Water Air Soil Pollut*, 228. DOI: 10.1007/s11270-016-3236-x.
- Li, Z., & Bowman, R.S. (2001). Retention of inorganic oxyanions by organo-kaolinite, *Water Research*, 35(16), 3771–3776. DOI: 10.1016/S0043-1354(01)00120-8.
- Mohamed, M.M. (2001). Heat capacities, phase transitions and structural properties of cation-exchanged H-mordenite zeolites. *Thermochim. Acta.*, 372 (1-2), 75–83. DOI: 10.1016/S0040-6031(01)00433-6.
- Mondales, K.D., Carland, R.M., & Aplan, F.F. (1995). The comparative ion exchange capacities of natural sedimentary and synthetic zeolites. *Miner. Eng.*, 8 (4-5), 535–548. DOI: 10.1016/0892-6875(95)00015-I.
- Ozola, R., Krauklis, A., Burlakovs, J., Klavins, M., Vincevica-Gaile, Z., & Hogland, W. (2019). Surfactant-Modified Clay Sorbents for the Removal of p-nitrophenol. *Clays and Clay Minerals*, 67 (2), 132–142. DOI: 10.1007/s42860-019-00015-2.
- Pils, J.R.V., & Laird, D.A. (2007). Sorption of tetracycline and chlortetracycline on K- and Ca-saturated soil clays, humic substances, and clay – humic complexes. *Environmental Science & Technology*, 41 (6), 1928–1933. DOI: 10.1021/es062316y.
- Prokop, G., Schamann, M., & Edelgaard, I. (2000). Management of contaminated sites in Western Europe. Topic Report. No 13/1999. European Environment Agency, Copenhagen.
- Reddy, K.R., Adams, J.F., & Richardson, C. (1999). Potential technologies for remediation of Brownfield. *Practice Periodical of Hazardous, Toxic, and Radioactive Waste Management*, 3 (2), 61–68.
- Rodríguez-Cruz, M.S., Sánchez-Martín, M.J., Andrade, M.S., & Sánchez-Camazano, M. (2007). Modification of clay barriers with a cationic surfactant to improve the retention of pesticides in soils. *Journal of Hazardous Materials*, 139 (2), 363–372. DOI: 10.1016/j.jhazmat.2006.06.042.
- Sarkar, B., Megharaj M., Shanmuganathan, D., & Naidu, R. (2013). Toxicity of organoclays to microbial processes and earthworm survival in soils. *Journal of Hazardous Materials*. 261, 793–800. DOI: 10.1016/j.jhazmat.2012.11.061.
- Stadlmair, L.F., Letzel, T., Drewes, J.E., & Grassmann, J. (2018). Enzymes in removal of pharmaceuticals from wastewater: A critical review of challenges, applications and screening methods for their selection. *Chemosphere*, 205, 649–661. DOI: 10.1016/j.chemosphere.2018.04.142.
- Stevenson, F.J. (1982). *Humus chemistry, Genesis, composition, reactions*. New York: John Wiley & Sons.
- Stevenson, F.J. (1994). *Humus chemistry, genesis, composition, reactions*. Second edition. New York: John Wiley & Sons.
- Thiebault, T., Guegan, R., & Boussafir, M. (2015). Adsorption mechanisms of emerging micro-pollutants with a clay mineral: Case of tramadol and doxepine pharmaceutical products. *Journal of Colloid and Interface Science*, 453, 1–8. DOI: 10.1016/j.jcis.2015.04.029.
- Valujeva, K., Burlakovs, J., Grinfelde, I., Pilecka, J., Jani, Y., & Hogland, W. (2018). Phytoremediation as tool for prevention of contaminant flow to hydrological systems. *Research for Rural Development*, 1, 188–194. DOI: 10.22616/rrd.24.2018.029.
- Wang, F., He, J., He, B., Zhu, X., Qiao, X., & Peng, L. (2018). Formation process and mechanism of humic acid-kaolin complex determined by carbamazepine sorption experiments and various characterization methods. *Journal of Environmental Sciences*, 69, 251–260. DOI: 10.1016/j.jes.2017.10.020.
- Yan, W., Hu, S., & Jing, C. (2012). Enrofloxacin sorption on smectite clays: effects of pH, cations, and humic acid. *Journal of colloid and interface science*, 372(1), 141–147. DOI: 10.1016/j.jcis.2012.01.016.
- Yariv, S., & Cross, H. (2002). *Organo-Clay Complexes and Interactions* (pp. 680). New York, USA, Marcel Dekker.

- Zamparas, M., Drosos, M., Deligiannakis, Y., & Zacharias, I. (2015). Eutrophication control using a novel bentonite humic-acid composite material BephosTM. *Journal of Environmental Chemical Engineering*, 3(4), 3030–3036. DOI: 10.1016/j.jece.2014.12.013.
- Zhang, L., Zhang, B., Wu, T., Sun, D., & Li, Y. (2015). Adsorption behavior and mechanism of chlorophenols onto organoclays in aqueous solution. *Colloids and Surfaces A: Physicochemical and Engineering Aspects*, 484 (5), 118–129. DOI: 10.1016/j.colsurfa.2015.07.055.
- Zhu, Z., Qiao, Y., Wang, N., & Cao, J. (2018). Decomposition characteristics of humic acid in boiler make-up water in power plants. *Applied Thermal Engineering*, 128, 1159–1164. DOI: 10.1016/j.applthermaleng.2017.09.096.

A SURVEY OF STATISTICS OF BUILDING FIRES IN LATVIA

*Edvins Grants

Latvia University of Life Sciences and Technologies, Latvia

*Corresponding author's email: edvins.grants@e-koks.lv

Abstract

A survey of 8985 records on all fires in Latvia in 2019 gathered by State Fire and Rescue Service was performed to find out if gathered data is suitable and complete for establishment of statistical database for fire protection engineering. The purpose of the survey is to assess suitability of provided content for further studies of the characteristic building fire occurrence probabilities in different building occupancy classes and to obtain solid background for calculations of national values of fire activation partial safety factors which could be implemented in national annex of Eurocode 1 part 1–2. Study contains data about the total number of building fires with relevance to their occupancy types and review of recorded fire causes for residential buildings that provide overall insight on typical causes of fires in dwellings.

Key words: fire protection engineering, fire statistics, fire causes, building occupancy class.

Introduction

Latvia is an Eastern European country which after regaining its independence from the Soviet Union is undergoing constant changes continues to develop and wants to reach the level of welfare equal to its Western European neighbours. With the resources available nation is working to achieve an equivalent, if not a better level of protection of people in their day-to-day lives where a significant improvement can be achieved by improving fire safety and protection levels of buildings and structures. Fire safety of buildings and structures is one of the indicators that indirectly provides information about the state of the surrounding environment and infrastructure – whether safety goals for buildings are achieved and whether the implemented protection measures improve the existing situation. Unfortunately, the compiled statistics (Brushlinsky *et al.*, 2019) on the total number of fires and the total number of deaths in Latvia over the period 1992–2017 are not flattering. The data collected so far show that the total number of fires in the country (Figure 1) have a tendency to fluctuate (State Fire and Rescue Service, 2020). Since 2014 the total number of fires has decreased but has not reached the lower point recorded at the beginning of the period under consideration. It means that the

total number of fires have maintained tendency to increase. Latvia has one of the highest annual and average number of fire deaths per 100,000 inhabitants among the member states of the European Union (Brushlinsky *et al.*, 2019).

In Cabinet of Ministers Order No. 7 (Cabinet of Ministers, 2019) and the State Audit Office's audit report (Latvia State Audit Office, 2016) are conclusions that the measures taken by State Fire and Rescue Services (VUGD) so far are not sufficiently effective. Taken measures are too general and strategic data collected to determine the effectiveness of the civil protection measures taken is too general and therefore aimless.

The importance of fire statistics is also highlighted by the Society of Fire Protection Engineers (Hall & Joglar, 2016), which provides a review of the main data analysis methods and references to the most significant studies to date. According to the Implementation of Eurocodes Handbook 5 (Schleich, 2005) the calculation methods presented in Eurocode 1 Part 1–2 (Latvian Standard, 2013) for determination of fire load densities and related partial safety factors are based on studies of building fire statistics (Fontana, Favre, & Fetz, 1999). However, conclusions and results found in aforementioned studies (Fontana,

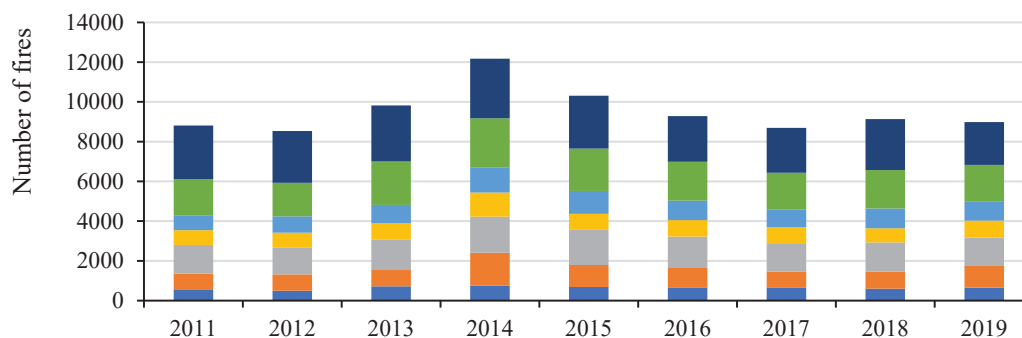


Figure 1. Annual number of fires in regions and largest cities of Latvia, (2011–2019) (State Fire and Rescue Service, 2020).

Favre, & Fetz, 1999) should be interpreted with caution when considering their applicability to the Latvian situation as the studies have been conducted on the situation in Switzerland where affecting factors such as administrative system and level of welfare differ. This is evidenced by the fact that the experience of mandatory insurance of buildings in Switzerland has already accumulated over 200 years (Fontana, Favre, & Fetz, 1999) whereas in Latvia mandatory insurance against fire and acts of God (natural disasters) is not yet practiced.

In this study, limited access dataset about registered fires in Latvia in 2019 provided by the State Fire and Rescue Service (VUGD) were evaluated. Forest fires are excluded.

The purpose of the survey is to assess provided content in the data collected by the VUGD and its relevance for further studies of the characteristic building fire occurrence probabilities in different building occupancy classes to provide engineering data for building fire protection engineers.

Materials and Methods

The research was conducted in several successive stages. In first stage analysis of relevant literature and regulatory documents were performed and organizations that collect data about building fires in Latvia were identified. In the next stage after evaluation of obtained public fire statistics (Brushlinsky *et al.*, 2019; State Fire and Rescue Service, 2020) and receiving data sets from VUGD (8985 recorded fires in 2019 in Latvia) information gap analysis was performed. In addition, data from the Ministry of Environmental Protection and Regional Development of the Republic of Latvia (VARAM) about the administrative territorial divisions of Latvia and their areas (Ministry of Environmental Protection and Regional Development of the Republic of Latvia, 2020) and publicly available data about population in 2019 were obtained (Central Statistical Bureau of Latvia, 2020).

At the third stage an in-depth analysis of the fire data was carried out during which the data grouping was performed by separating the building fires from other fires. Number of building fires were compared between regions of Latvia by taking in-to account population in each of the territories. Comparison of data was based on dispersion analysis. The descriptive statistics were performed using computer software 'R v. 3.6.2.' but results are presented using tables, graphs and maps created using 'iMapBuilder Online v11.064'.

Results and Discussion

Survey of publicly available fire statistics

The only public source of information on registered fires in Latvia are data summaries provided by VUGD

which are available as annual reports 'Rescue, fires and their consequences' (State Fire and Rescue Service, 2020) and annual 'Public activity reports' (State Fire and Rescue Service, 2019). An additional source of information about fires in Latvia is data gathered by 'International Association of Fire and Rescue Services' (CTIF – Comité Technique International de prevention et d'extinction de Feu), whose member state is Latvia (Brushlinsky *et al.*, 2019).

It must be mentioned that interesting data collection is presented by University of Oxford – 'Our World in Data' (Metrics and Evaluation IHME, 2018). In this data collection are reviews about main causes of death including fires worldwide.

Open access information data collections show that they deal with fires and their consequences in general, without distinguishing building fires from other fire types. Such information does not provide accurate clues about the actual fire hazards in buildings and the likelihood of a fire occurrence. The structure of the content of the available statistics is presented in Table 1.

Data sources provide a general insight into:

- the number of fires in different administrative territories of the state without information how they are related to types of fires;
- the number of people injured and killed in fires in a country without relevance to the types of fires or their causes;
- distribution of the total number of fires by type without relevance to the administrative territories;
- distribution of total number of fires by type of cause, without linking it to fatalities or types of fire.

Analysis of data of building fires

According to the Law on Administrative Territories and Populated Areas (The Parliament of the Republic of Latvia, 2008), Latvia is currently divided into 119 administrative territories – 110 Municipalities and 9 cities, including Riga the capital of the country. For general overview of distribution of fire gradation of the number of fires by population density for each municipality of Latvia was established. Simplified summary on population density in administrative territories of Latvia in the beginning of 2019 is demonstrated in Figure 2.

The highest population densities are in the cities where average population density is 1100 (± 366.572 , $\alpha=0.05$) citizens per km² and municipalities around the capital city Riga where population density tends to be higher than 60 citizens per km², but it is not higher than 210 citizens per km² (Figure 2). In other parts of Latvia population density is low – below 30 citizens per km² with exceptions of Cesis and Aizkraukle municipalities. Population density in Riga capital city of Latvia is above 2000 citizens per km². For

Table 1

Data availability in open access data sources

Information Type	DS 1*	DS 2**	DS 3***	DS 4****
Total number of fires	✓	✓	✓	✗
Number of fires in administrative territories of Latvia	✓	✓	✗	✗
Type of accident	✓	✓	✓	✗
Number of injuries and fatalities	✓	✓	✓	✓*****
Assumed reason of fire incident	✗	✓	✗	✗
Number of rescue services performed other than firefighting	✓	✓	✗	✗
Type of fire service calls	✗	✓	✓	✗
Number of fire safety control in buildings	✗	✓	✗	✗
Number of injured firefighters	✗	✗	✓	✗
Comparison of firefighting equipment	✗	✗	✓	✗
Fire service personnel by gender	✗	✗	✓	✗

- ✓ Information available in the data collection
- ✗ Information not available in the data collection
- * DS 1 – State Fire and Rescue Service annual reports ‘Rescue, fires and their consequences’(State Fire and Rescue Service, 2020)
- ** DS 2 – State Fire and Rescue Service annual ‘Public activity reports’(State Fire and Rescue Service, 2019)
- *** DS 3 – CTIF annual reports (Brushlinsky *et al.*, 2019)
- **** DS 4 – University of Oxford data collection – ‘Our World in Data’ (Metrics and Evaluation IHME, 2018)
- ***** Data collection provides information about death rates only

comparison of municipalities, administrative territories of Latvia are usually grouped in larger regions called Regions of planning or Statistical regions.

Looking at the distribution of building fires graded by population density classes and regions (Figure 3), it can be seen that the largest number of fires appears in regions with the highest population densities and in the

territories with lowest population density. Increased number of fires in territories with low population density can be explained with the fact that territory within this population class covers the largest part of the country. Largest number of building fires per 1000 inhabitants is in large cities of republic (Figure 4); however, it seems to be proportional with the density

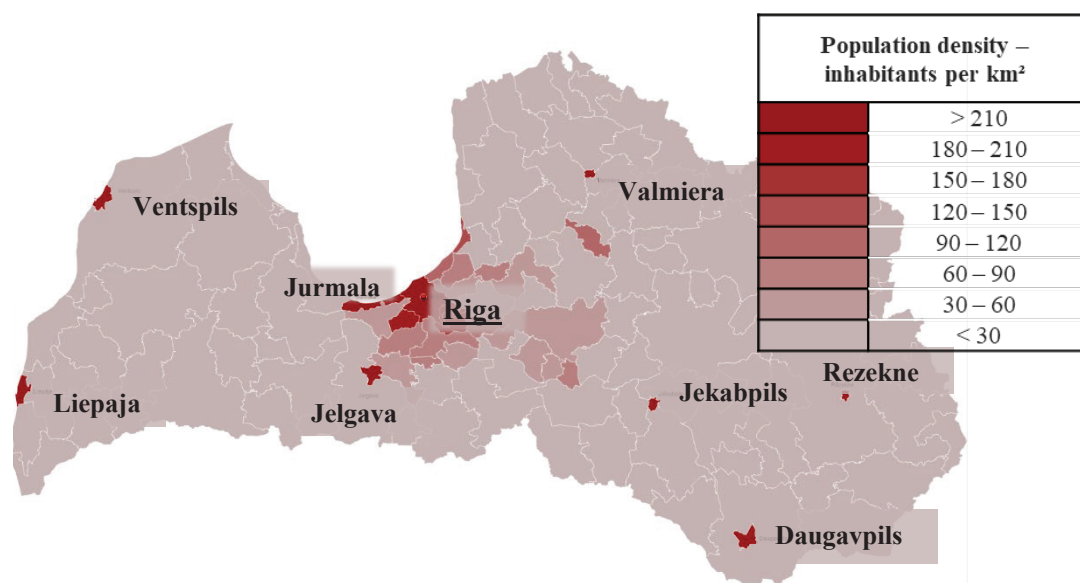


Figure 2. Characteristic population density in administrative territories of Latvia.

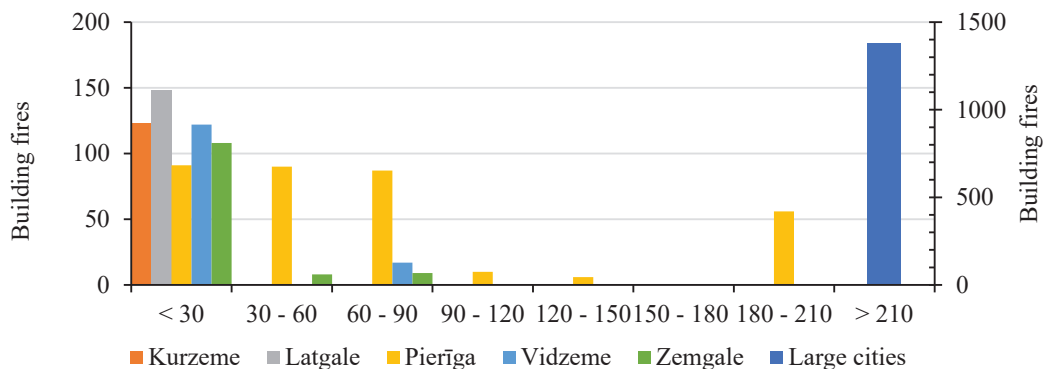


Figure 3. Building fires by population density in regions of Latvia in 2019.

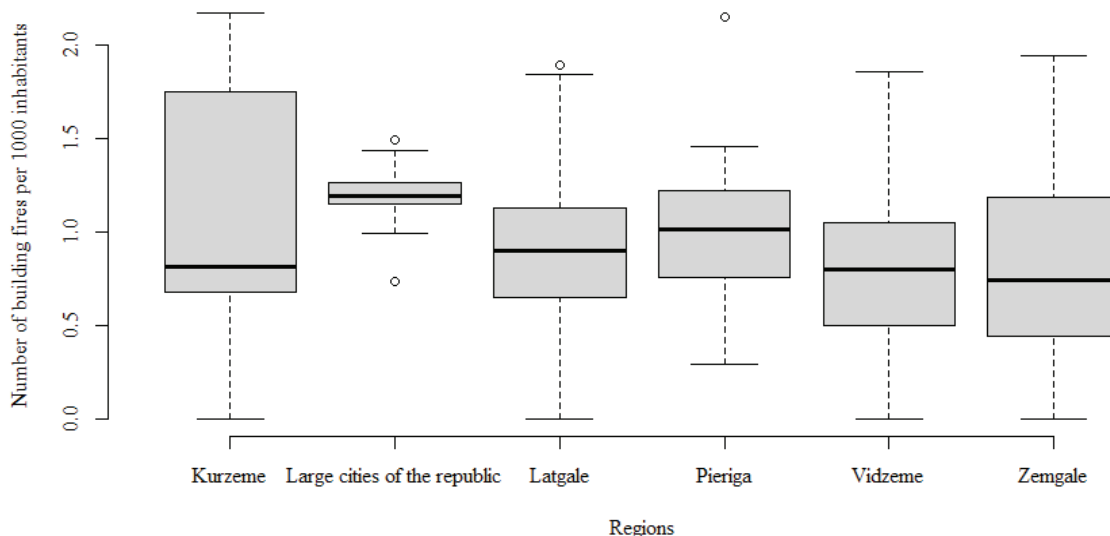


Figure 4. Number of building fire per 1000 inhabitants in regions of Latvia. Median (middle black line), confidence region (grey box), maximum and minimum values within range of 1,5 times confidence region (dashed lines), outliers (dots).

of population because by comparing dispersions of building fires per 1000 inhabitants (Figure 4) of each municipality, it is found that there is no significant difference in number of building fires among regions of Latvia ($p > 0.05$).

Informative background (Schleich, 2005) for theoretical basis of Eurocode 1 part 1 – 2 (Latvian Standard, 2013) describe important studies (Fontana, Favre, & Fetz, 1999) of building fires where data was obtained by surveying insurance companies providing mandatory building insurance services in cantons of Switzerland and therefore data is comprehensive, because it covers all buildings in the country. Data also include cases in which fire and rescue services were not called because the amount of fire was negligible or self-extinguished but an insurance claim was initiated. The situation in Latvia is different. Neither VUGD nor the insurance companies in Latvia carry out comprehensive inventory and gradation of all buildings in the country. So the collection of

data about building fires that would be equivalent to data mentioned in current studies (Fontana, Favre, & Fetz, 1999) might prove to be a challenging task. In the light of the information above contacts have been established with the responsible officers for data management and gathering from operational reports in VUGD and a mutual cooperation agreement has been concluded. Within the framework of the agreement an expanded information database on fires in Latvia in 2019 was obtained for research purposes where sensitive information had to be protected and handled with care. At the same time other cooperation has been initiated with some of the national insurance companies and will be expanded in future. Further in this paper the results obtained from the data received from VUGD will be presented.

The relevant fire database does not contain information about fatalities, so it is not possible to link specific building occupancy classes and causes of fire to the number of casualties. To assess building fires

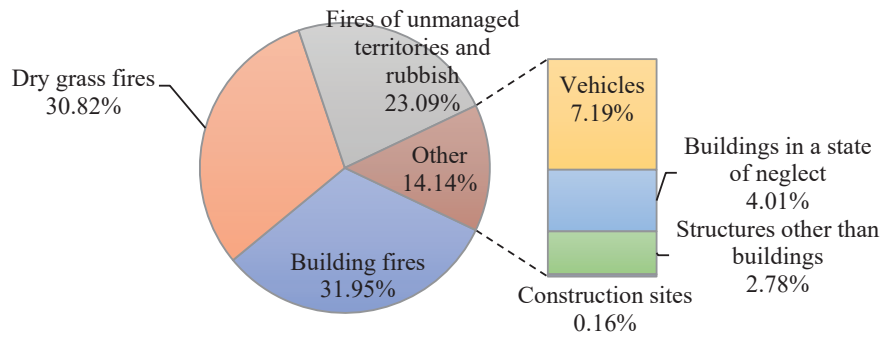


Figure 5. Distribution of recorded fires by fire origin.

operational information about all recorded 8985 fire accidents in Latvia in 2019 was reviewed. To present distribution of fires by fire origin with relevance to the occupancy of the place under fire all on the basis of operational records all cases were sorted into groups of fire origin as presented in Figure 5. Classification is slightly different from already used classification in data tables because there were encountered some inconsistencies. For example: there are cases when garage premises are classified either as non-residential premises or transport buildings. Inconsistencies encountered also with structures such as poles for electricity land lines, where, for example, if the pole is built in the territory where manufacturing facilities are, then it is classified as fire in manufacturing facility etc. According to this data review of total number of fires in Latvia is distributed in seven main groups – Building fires (31.95%), Dry grass fires (30.82%), Fires of unmanaged territories and waist (23.09%), Vehicle fires (7.19%), Buildings in a state of neglect (4.01%), structures (2.78%) and construction sites (0.16%).

Data grouping revealed that the previous classification of fires by fire origins (State Fire and Rescue Service, 2020) is based on the terminology and definitions given in Regulation No. 238 – Fire

Safety Regulations (Cabinet of Ministers, 2016) where number of definitions for fire origins is smaller than number used and necessary for data classification in practice. Also, in practice used fire origin classification has caused problems for VUGD officers to grade fire origin in special cases when fire occurs in first floor commercial premises of nine storey residential building. Afore mentioned and similar cases are causing difficulties for fire protection engineers, structural engineers and architects as well when adequate fire protection level has to be established with relevant fire protection measures. The fact that fire fighters and building engineers have to use regulations with inconsistent classifications for building occupancies is not helpful either. For example, national Regulations No. 333 – LBN 201-15 (Cabinet of Ministers, 2015), No. 238 – Fire Safety Regulations (Cabinet of Ministers, 2016) and LVS EN 1991 – 1 – 2 (Latvian Standard, 2013) each have their own classifications for building occupancies. This situation makes room for interpretations that can cause errors in building designs. To solve this situation further studies about possible solutions how to harmonise different classifications of the same purpose between national regulations and European standards might prove useful.

Table 2

Distribution of building fires by occupancy types defined in LBN 201-15

Building occupancy types according LBN 201-15 (Cabinet of Ministers, 2015)		Distribution of building fires, %
Type I	Dwellings and residential buildings	84.01
Type II	Accommodation buildings – hotels, hostels etc.	0.62
Type III	Hospitals, prisons or other similar establishments	0.58
Type IV	Public buildings for commercial purposes and places of assembly	4.66
Type IVa	Education buildings and kindergartens	0.31
Type V	Administrative buildings and office buildings	1.69
Type VI	Industrial buildings and storages	6.08
Type VIa	Rural production buildings and structures	1.64
Type VII	Garages and similar buildings	0.41

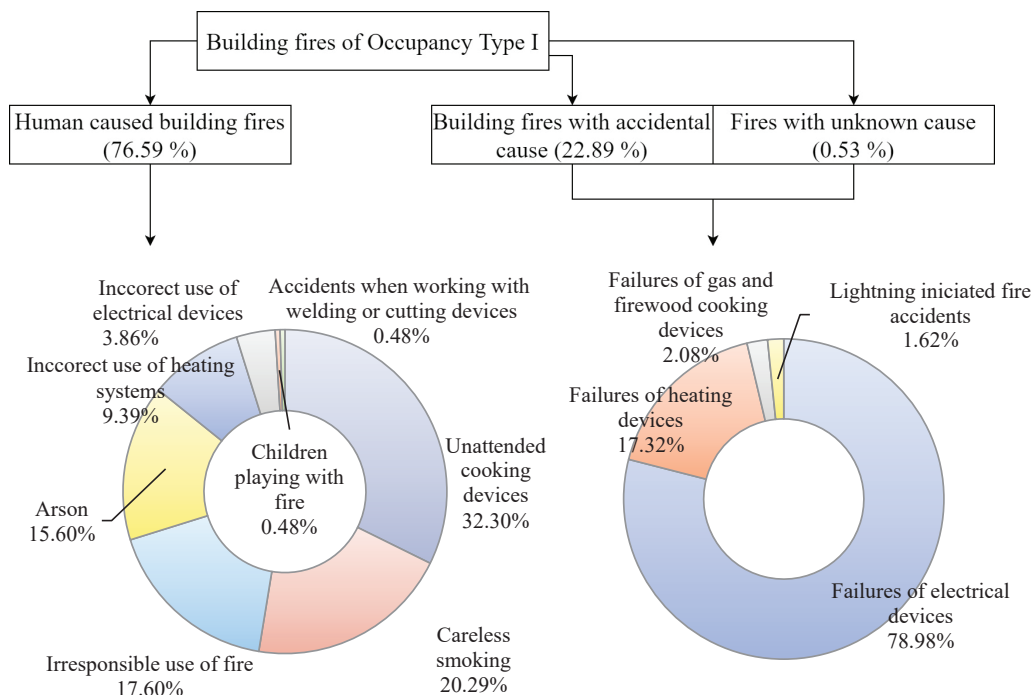


Figure 6. Distribution of Occupancy type I building fires by nature of reasons causing fire and assumed causes.

Table 2 demonstrates how building fires are distributed between different occupancy types if data are grouped according to Cabinet of Ministers Regulation No. 333 (Cabinet of Ministers, 2015) instead of Cabinet of Ministers Regulation No. 238 (Cabinet of Ministers, 2016).

Largest part of recorded building fires (84.01%) in Latvia in 2019 can be classified as residential building fires. Number of building fires of other occupancy types are significantly smaller. For occupancy type I building fires most common reasons causing fire can be divided into three groups (Figure 6) where fires caused by human actions take first place with 76.59% but accidents without human interventions cover only 22.89% of recorded cases. Interestingly, among fire accidents caused by human, largest part of records comprises of cases where a fire accident happened because of unattended cooking devices (32.30%), careless smoking (20.29%) and irresponsible use of fire or open flame (17.6%). In order to determine the probability of a fire occurring for any of occupancy type buildings the total number of buildings in the country grouped by occupancy types should be known. Information about number of buildings in the country where all existing buildings would be grouped by occupancy according to LBN 201-15 were not available yet.

Conclusions

1. The data obtained so far are inadequate to develop detailed conclusions about the causes of the fires

and to determine the probabilities of building fires for each of the occupancy type, since the data were not comprehensive and did not include the total number of buildings in the country for each occupancy type.

- There are inconsistencies and differences in the classification of buildings according to their occupancy type, not only between national regulations in the fields of firefighting and building design, but also between Latvian and European regulations. This situation should be improved in order to simplify the work with engineering data and to develop a common understanding of building fires and design at national level among related industries and harmonise it with European level.
- Comparing the administrative territories of Latvia by the number of fires, it was found out that the number of building fires is proportional to the population of the respective territories. There is no significant difference between the regions of Latvia in the number of building fires per 1000 inhabitants. This finding aligns with the distribution of fire by nature of fire cause for residential buildings where it was found that largest part of residential fires is caused by careless human actions.
- There is a lot of information and records gathered about building fires in Latvia through past years; however, not all of the data can be used for fire protection and structural engineering. This study provides first insight in current situation and gives hints about data necessary to be gathered in

future studies to help fire engineers by providing useful engineering data.

Acknowledgement

This study was supported by Forest Sector Competence Centre of Latvia within framework of

research project – 1.2.1.1/18/A/004 – P1. Special gratitude shall be expressed to State Fire and Rescue Service for support with data and useful recommendations.

References

- Brushlinsky, N., Ahrens, M., Sokolov, S., & Wagner, P. (2019). *World Fire Statistics, Report No. 24* (p. 64). CTIF, International Association of Fire and Rescue Services, National committees CTIF of Russia, Germany, USA.
- Cabinet of Ministers. (2015). *Ministru kabineta noteikumi Nr. 333 par Latvijas būvnormatīvu LBN 201-15 'Būvju ugunsdrošība' (Cabinet Regulation No. 333 Regarding Latvian Building Code LBN 201-15 'Fire Safety of Structures')*. Latvijas Vēstnesis, 30.06.2015., 125(5443), Cabinet of Ministers. Retrieved March 3, 2020, from <https://likumi.lv/ta/id/275006-noteikumi-par-latvijas-buvnormativu-lbn-201-15-buvju-ugunsdroshiba>. (in Latvian).
- Cabinet of Ministers. (2016). *Ministru kabineta noteikumi Nr. 238, Ugunsdrošības noteikumi (Cabinet Regulation No. 238, Fire Safety Regulations)*. Latvijas Vēstnesis, 78(5650), 22.04.2016. Cabinet of ministers. Retrieved on March 5, 2020, from <https://likumi.lv/ta/id/281646-ugunsdroshibas-noteikumi>. (in Latvian).
- Cabinet of Ministers. (2019). *Ministru kabineta rīkojums Nr. 7, Konceptuālais ziņojums 'Par valsts politiku ugunsdrošības jomā' (Cabinet Order No. 7, Principal Report 'On State Policies in Field of Fire Safety')*. Latvijas Vēstnesis, 11.01.2019. No. 8(6347). Cabinet of Ministers. Retrieved March 4, 2020, from <https://likumi.lv/ta/id/304174-par-konceptualo-zinojumu-par-valsts-politiku-ugunsdroshibas-joma>. (in Latvian).
- Central Statistical Bureau of Latvia. (2020). *ISG020. Population number and its change by statistical region, city, town and county*. Retrieved March 3, 2020, from http://data1.csb.gov.lv/pxweb/lv/iedz/iedz_iedzskaits_ikgad/ISG020.px/table/tableViewLayout1/.
- Fontana, M., Favre, J.P., & Fetz, C. (1999). A survey of 40,000 building fires in Switzerland. *Fire Safety Journal*, 32(2), 137–158. DOI: 10.1016/S0379-7112(98)00034-4.
- Hall, J.R.J., & Joglar, F. (2016). Probability and Statistics. In *SFPE Handbook of Fire Protection Engineering* (5th Edition, pp. 2827–2874). Springer New York. DOI: 10.1007/978-1-4939-2565-0_73.
- Latvia State Audit Office. (2016). *Audita ziņojums Nr. 2.4. 1-9/2015. 'Vai valstī īstenotie ugunsdrošības pasākumi ir pietiekami?' (Audit report No. 2.4. 1-9/2015. 'Are Fire Safety Measures Established Sufficient?')* (p. 87). Riga, Latvia State Audit Office (Report No. 2.4.1-9/2015). (in Latvian).
- Latvian Standard. (2013). *LVS EN 1991-1-2:2003/AC:2013. Eurocode 1: Actions on structures – Part 1-2: General actions – Actions on structures exposed to fire*, (p. 59). CEN/TC 250, Brussels.
- Metrics and Evaluation IHME. (2018). *Global Burden of Disease Collaborative Network. Global Burden of Disease Study 2017 (GBD 2017). Results*. Metrics and Evaluation IHME; Seattle, United States: Institute for Health, Retrieved March 5, 2020, from <https://ourworldindata.org/grapher/fire-death-rates>.
- Ministry of Environmental Protection and Regional Development of the Republic of Latvia. (2020). *Information about municipalities in Latvia*. Retrieved March 4, 2020, from http://www.varam.gov.lv/lat/darbibas_veidi/pasv/. (in Latvian).
- Schleich, J.-B. (2005). Chapter III – Calibration of Reliability Parametres. In *Implementation of Eurocodes, Handbook 5, Design Of Buildings For The Fire Situation* (pp. III-1-III-30). Leonardo da Vinci Pilot Project CZ/02/B/F/PP-134007, retrieved March 3, 2020, from <https://eurocodes.jrc.ec.europa.eu/showpublication.php?id=66>.
- State Fire and Rescue Service. (2019). *Valsts ugunsdzēsības un glābšanas dienesta publiskie pārskati no 2010.–2018. gadam (Open Access Reports on Annual Activities of State Fire and Rescue Service From 2010–2018)*. Retrieved March 5, 2020, from. https://www.vugd.gov.lv/lat/aktualitates/publikacijas/gada_publiskie_parskati. (in Latvian).
- State Fire and Rescue Service. (2020). *Pārskati par ugunsgrēkiem un to radītajām sekām no 2011.–2019. gadam (Reports About Fires And Their Consequences From 2011–2019)*. (p. 23). Retrieved March 4, 2020, from <https://www.vugd.gov.lv/lat/aktualitates/statistika>. (in Latvian).
- The Parliament of the Republic of Latvia. (2008). Administratīvo teritoriju un apdzīvoto vietu likums (Law On Administrative Territories and Populated Areas). In *Latvijas Vēstnesis No. 202, 30.12.2008*. Retrieved March 6, 2020, from <https://likumi.lv/ta/en/en/id/185993-law-on-administrative-territories-and-populated-areas>. (in Latvian).

DURATION OF LOAD EFFECTS ON DEVELOPMENT OF DEFORMATIONS IN BOLTED MOMENT CONNECTION

***Janis Fabriciuss, Lilita Ozola**

Latvia University of Life Sciences and Technologies, Latvia

*Corresponding author's email: janis.fabriciuss@inbox.lv

Abstract

Experience saved in the construction industry shows that the timber portal frames with semi-rigid connections at knee joint exhibit permanently increase displacements at the knee and apex point. Normally, timber portal frame with semi-rigid knee joint connection is made with mechanical fasteners located in double circles and cannot be designed without relevant rotation at connection during structures' exploitation time. The only way to increase connection rigidity is to rise distance from fasteners location at connection, but at the same time, the tension and shear stress become significant at the external section of members. The previous experience is obtained by a model testing showing that deformations at semi-rigid connections are non-linear. These were tests under short-term load and did not disclose creep effects, which can be significant.

This study is aimed at the examination of increasing deformations with time under constant static load (creep effects) in semi-rigid dowelled connection.

Experimental test models were made and set under long-term load in controlled environmental conditions (heated laboratory room). Results show a significant creep influence to decrease connection stiffness.

Corresponding numerical test of orthotropic 3d model by Dlubal RFEM software tools was performed analyzing the value of expected deformations. Results of the numerical test showed that friction between timber elements and extra nuts on bolts can increase connection stiffness.

Research results in this stage show that the creep can affect connection stiffness more than expected. Also, experimental test results showed lower deformation values comparing with the ones obtained by the numerical test.

Key words: semi-rigid timber connection, creep, rotational movement, modeling of connection, portal frames.

Introduction

Portal frame is one of the most used structural forms in the modern construction industry because of the extra free space under the bearing structure, as well as much shorter time is needed for assembling in the construction site. Steel portal frames are well-known structures, but there is an option to use more renewable resources and choose the same solution using timber material. Definition of appropriate design presumptions for the knee joint both made as glued finger joint and by mechanical fasteners, one is the core problem in the design of timber portal frames. The portal frame structure remains stable during service if the column and rafter sections are stiff enough to transfer stresses induced by external loads, and knee joints are so rigid that small rotational movements probably developed do not cause global deformations of a portal frame out of limits. Knee joint connection made as glued finger joints ensure high rigidity and fully stable three-hinged portal frame structure. But glued finger joint connection normally is produced in the factory far from a building site. Therefore, the main problem is the transportation of prefabricated big scale units from the factory to the building site. Due to transport limitations, it is also a limited area of use of timber portal frames with glued finger joints in the knee. Integration of the semi-rigid bolted connection in the knee joint resolves the transportation problem, as column and rafter members can be assembled together by mechanical fasteners at the building site.

Semi-rigid connection is normally made by mechanical fasteners (bolts) located in double circles. This connection characterizes specific behavior features under the load. Non-linear deformation is in progress. These effects were discussed previously in other investigations (Schweigler, Bader, & Hochreiner, 2018). The connection exhibits a relevant rotational movement. Therefore, rigidity of connection is decreased. The rigidity of semi-rigid connection can be increased by the relocation of mechanical fasteners, i.e., increasing the distance between fasteners in an external circle, as well as from the center of connection. Also, using a higher strength class of glulam can lead to an increase of connection stiffness, but this solution is ineffective in an economic sense. Another problem in semi-rigid bolted connections is shear and cross-grain tension stresses induced in wood sections between mechanical fasteners and timber, especially in zones where the distance between fastener and connection center is higher. Ormarsson showed the effect in his investigation (Ormarsson, Dahlblom, & Nygaard, 2010).

One of the first researchers who investigated the behaviour of semi-rigid timber element connections with a purpose to define the design model for bearing capacity calculations, were Racher (Bouchair, Racher, & Bocquet, 2007), Porteous, Kermani (Porteous & Kermani, 2013). Leichti summarized that resisting moment at semi-rigid knee joint can be expressed as the function of stiffness properties (Leichti *et al.*, 2000). Assumptions for the calculation of connection

bearing capacity was described in the previous article (Ozola & Fabriciuss, 2019). Researchers also defined that the geometrical center of mechanical fasteners in connection can also be defined as a rotational center of connection or simply – a center of joint (Bouchair, Racher, & Bocquet, 2007). Detail investigation of semi-rigid moment connections has been performed by Fokken (Fokkens, 2017).

Stiffness of the semi-rigid connection can be characterized by a rotational stiffness modulus K_{ϕ} expressed as the moment value inducing the rotation between connected elements on an angle of one radian ($\text{kNm}\cdot\text{rad}^{-1}$). For portal frame design considerations, it is aimful to express the rotational stiffness modulus in terms of design moment value M_d : $K_{\phi} = k_{sr} \cdot M_d \cdot \text{rad}^{-1}$, where k_{sr} is rigidity factor to be determined. In Eurocode (Europe structural engineers guideline) slip modulus k_{sr} is defined only for linear displacement – connection where force direction transferred by fasteners is usually in the same direction as timber grain (European committee for standardization, 2008). At a knee connection of timber portal frame force from a beam element to mechanical fastener and column element is transferred in multiple directions for individual bolts regarding wood fibers, so Eurocode methodology could not be applied safely in this case.

All previously obtained experimental test results were collected from short-term loading without making long-term loading tests to investigate creep

effects on semi-rigid connection deformations in time. Eurocode did not give exact information about creep effects on a semi-rigid connection. As an example, the researcher Hanhijärvi (Hanhijärvi, 2000) made a significant impact on making background analysis of the creep phenomena.

This investigation is aimed at revealing the difference between theoretical numerical test results with experimental test results and finding more significant factors that can affect the rotational stiffness of semi-rigid connection during service life.

The main tasks of this study: 1) design and determination of bearing capacity of L-type model according to Eurocode 5 (European committee for standardization, 2008), 2) performing of experimental tests for L-type models in long term loading and collection of data daily, 3) numerical test of L-type model using Dlubal RFEM software tools, 4) comparison of test results and conclusions.

Materials and Methods

The methods appropriate for attaining the aims of this investigation were chosen. The theoretical model for the numerical test was constituted correspondingly choosing Dlubal RFEM software tools and options for introducing of spring hinges in order to resolve the non-linear model. The experimental model was made in a laboratory and tested under a long-term static load. Test specimens are of L-type models simulating

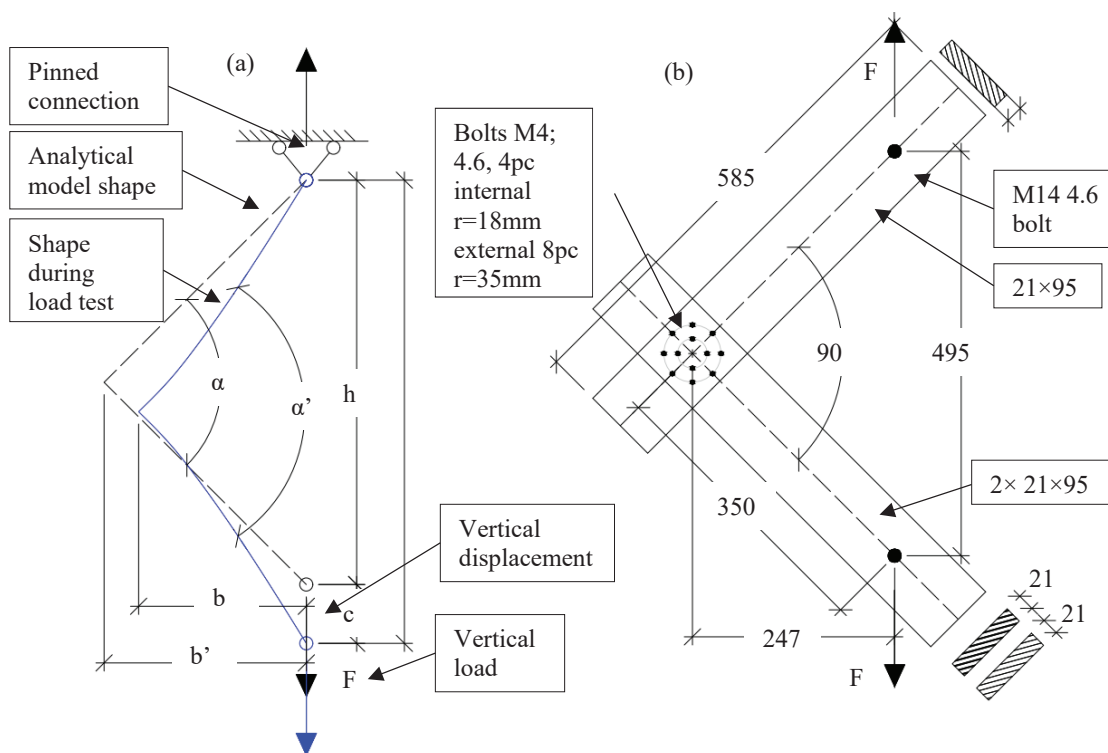


Figure 1. L type model analytical shape and dimensions (mm); a – analytical shape; b – shape during load tests in a laboratory.

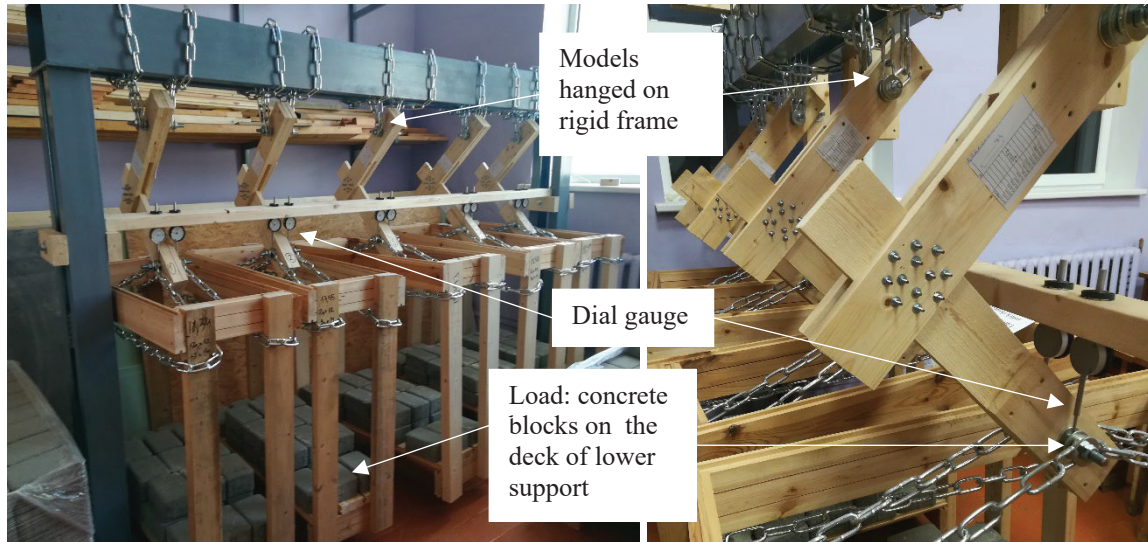


Figure 2. Experimental setup for long-term tests of L-type models.

the shape of the beam and column connection in the timber portal frame (Figure 1a). Simmilar model shape has been taken in Awaludin research (Awaludin etc. 2010).

The experimental models are made of softwood lumber (spruce *Picea Abies*), cross-section 21×95mm (Figure 1b). The moisture content of wood is in the range of 5% to 11%, it is measured using the Wood Moisture Meter MD-2G. The average mass density of the wood varies from 330 kg·m⁻³ to 400 kg·m⁻³ in dry condition. Semi-rigid connection is formed by twelve bolts M4 (metric threaded rods, d=4 mm grade 4.8, DIN 976), which are placed around two circles. Four bolts are located around the internal circle and

eight bolts are placed around the external one. All bolts from both sides were fixed by washers and nuts. Hole diameters for rods are the same as the nominal for rods; therefore, any free movements in connection were prevented. The lumber was free of cracks and straight of grain. Some small knots were found in lumber apart from the fastener location area. Support joints are assembled using bolts M14 (metric threaded, d=14 mm, grade 4.8) in the center of lumber elements. Higher support was hanged to the rigid frame and vertical downward load is attached to lower support. Before the load was attached, models were stiffened with gasket – 21×95mm timber elements at the support zone. In total five experiment models were made.

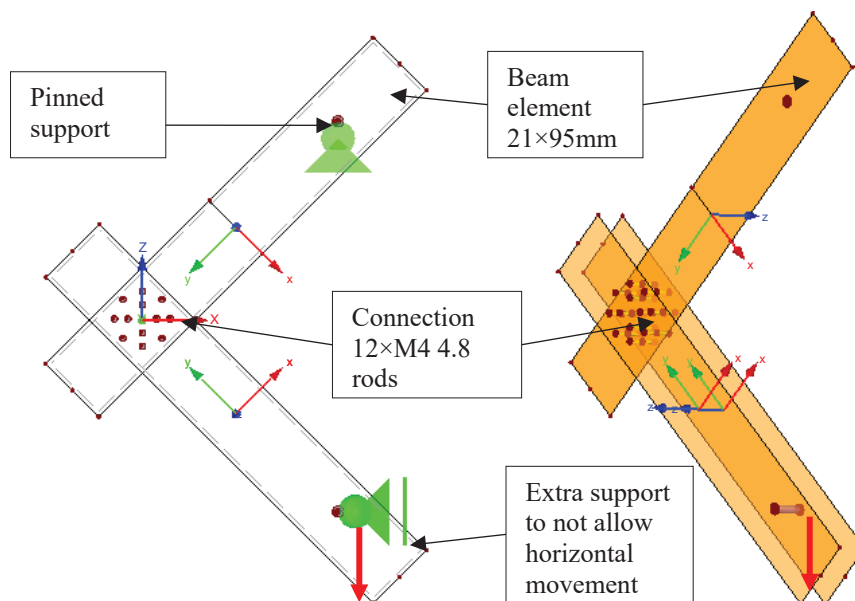


Figure 3. Analytical L-type model in Dlubal (RFEM).

Experimental tests were performed in the laboratory of Structural Engineering, Faculty of Environment and Civil Engineering, Latvia University of Life Science and Technologies, from April 2019 till now. Research was made under controlled microclimate conditions (heated room).

The load was attached manually by concrete weights (Figure 2). The experimental models were loaded stepwise: during the first 60 minutes till load reaches approximately 50% from overall semi-rigid connection load-bearing capacity – 1160 N at lower support. Average models bearing capacity was 524 N·m at connection. During stepwise loading, vertical displacement was measured at lower support by dial gauges. Dial gauges were mounted on an independent stiff beam. In the second step, the constant vertical load was kept for nine months. Vertical displacements were measured daily during all tested time simultaneously performing monitoring of air temperature and relative humidity.

The analytical model was constituted to simulate the experimental model as close as possible by tools of Dlubal RFEM. Beam and column elements were modeled as surface elements and rods were modeled as members (Figure 3). The material of surface elements was classified as softwood lumber of strength class C30 assessed by visual grading rules. Rod member connections at crossing points with lumber surface elements were defined as rigid with spring constant c_{ux} . Spring constant was defined differently in every rod taking into account the angle between grain direction and shear force direction transferred by a fastener. The value of spring constant varied from 3430 kN·m⁻¹ up

to 4830 kN·m⁻¹ depending on force angle to the grain direction.

Results and Discussion

The measurements of the vertical movement were collected for every L-type model during long-term loading. Models demonstrated a huge vertical movement on the first day, which was approximately 60% from overall deformation. Later, an average increase of displacements was 1 mm per day for every of sixty test days. Vertical displacements measured serve as the main characteristic for rotational deformation of connection. Increase of deformation by time can be characterized by linear relationship (1);

$$k_t = \Delta_t \cdot T^{-1} \tag{1}$$

where Δ_t is the deformation at time.

Average deformations in time for L-type models were $kt=0.041 \text{ mm} \cdot \text{day}^{-1}$. All results from experimental investigations are collected in Figure 4. Average vertical displacement for the model member after one day was 6.9 mm, and after 280 days – 11.6 mm.

The development of deformations in time may be characterized by the relative creep or creep coefficient, which is a general nondimensional indicator of creep (Hunt, 1999). The relative creep is expressed in terms of the initial elastic deflection (u_0):

$$c_r(t, T, MC) = \frac{u_t - u_0}{u_0} \cdot 100\%, \tag{2}$$

where u_t is the displacement at a time (t) in step with air temperature (t) at a laboratory and air humidity (p).

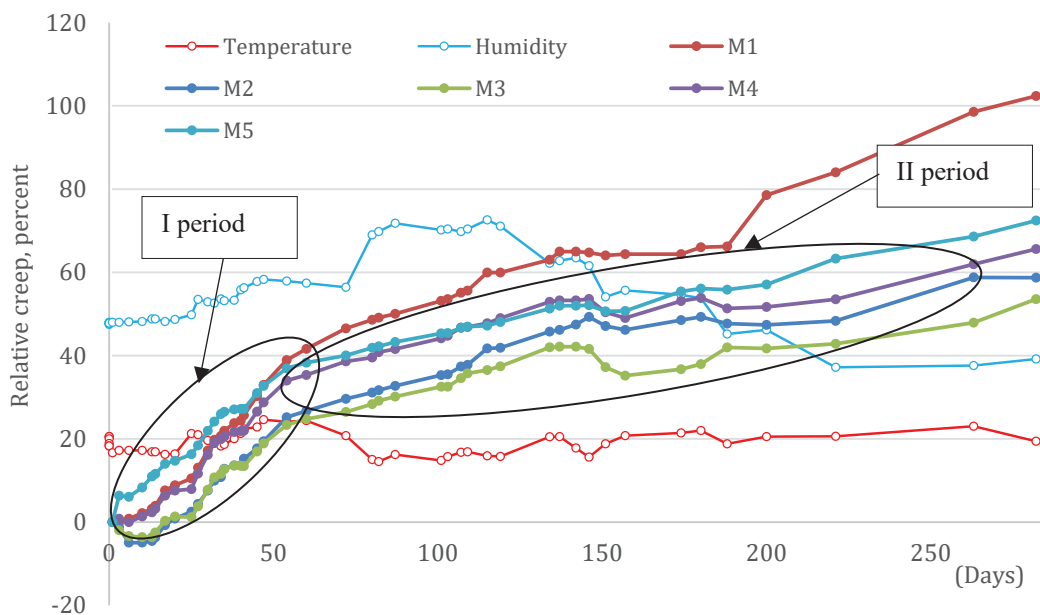


Figure 4. Relative creep for the models with corresponding humidity and temperature data at 280 days loading test.

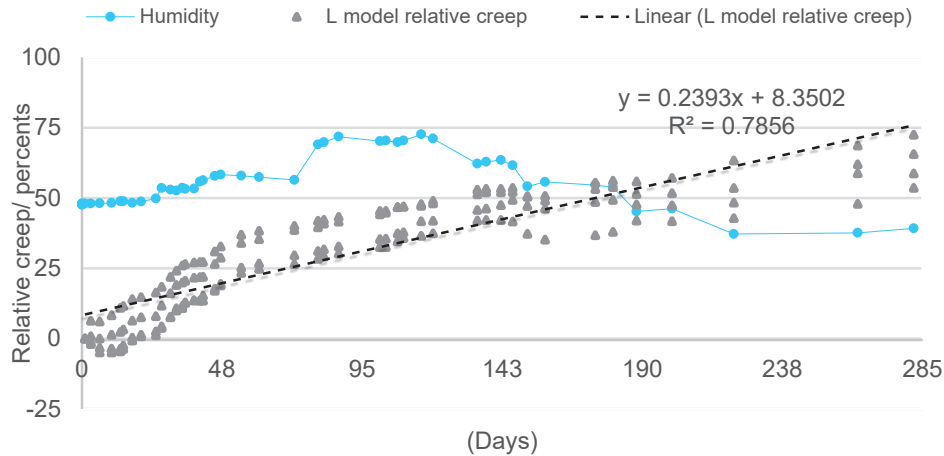


Figure 5. Approximation of average relative creep values in the time data at 280 days loading test.

Graphs for the development of relative creep during the time are shown in Figure 4. Almost all models show a similar increase in relative creep in time, except Model No 1. The average relative creep increase after 60 days was 30% but after 280 days it was 60%. Development of relative creep for L-type moment-resisting connections can be described distinctively in two periods of time. In the first period, creep permanently increases for the first 60 days under constant air temperature and humidity. In the second period more slowly creep increase is observed and also the influence of air humidity changes is more affecting (Figure 5).

Choosing the best regression model for this type of model is difficult because of on non-linear relationship

between relative creep and time. However, during the investigation, different regression models were examined to describe an increase of creep in time (Figure 5).

The theoretical model is shown in Figure 6. The apex point was fixed, and external vertical force 1160 N (the same as for experimental models) was attached at the lower point. Theoretical results showed that vertical movement of the L-type model is expected of $w=29.2$ mm and vertical displacement of the lower point was $w=22.2$ mm. Note, that the friction between timber elements was not taken into account by theoretical model and also all fastener at connections were without nuts and plates.

According to measured displacements during long-term tests, the rotational stiffness values K_{φ} were

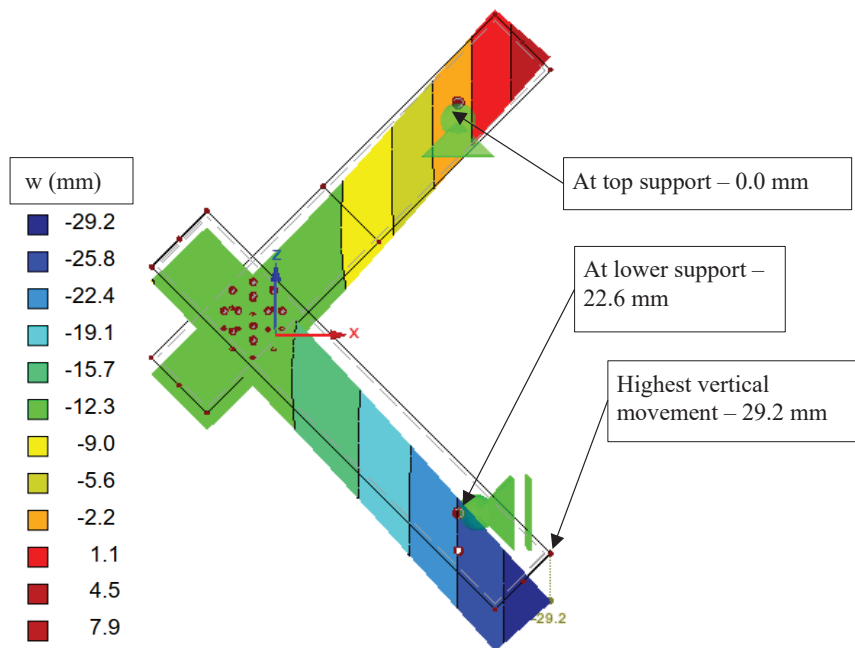


Figure 6. Theoretical model vertical deformations w according to test load.

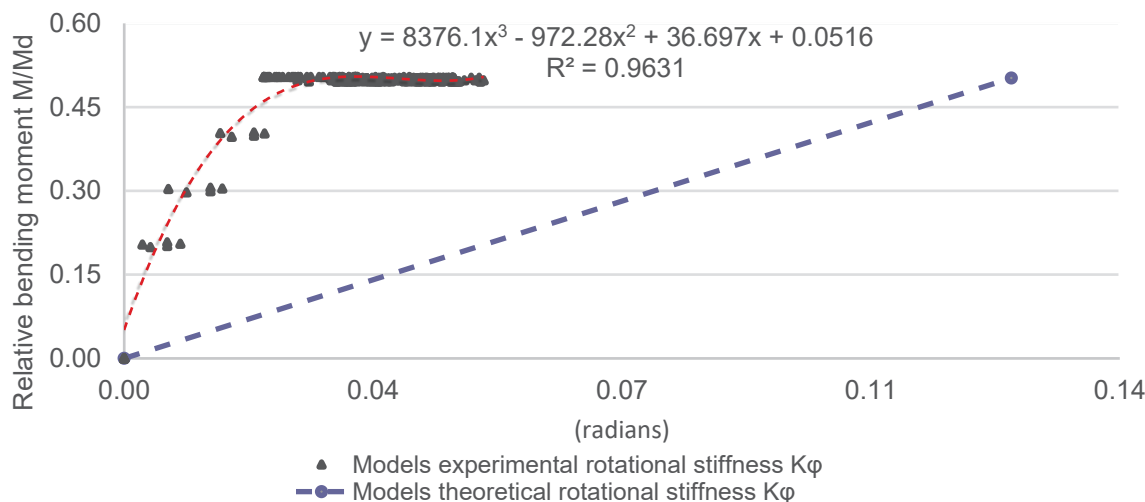


Figure 7. Models theoretical and experimental rotational stiffness at long term loading.

determined. The previous study (Ozola & Fabriciuss, 2019) proved that semi-rigid connection deformations became non-linear after moment reached 50–60% from semi-rigid connection bearing capacity. In this investigation, experimental L-type models were loaded average on 52% from design bearing capacity and non-linear behavior has to be proved by results. The graph (Figure 7) shows that deformations at the start were linear. During long-term loading, the creep deformations are decreasing connection rigidity, permanently increasing the rotational movement. The average rotational stiffness at first day was $K_{\phi}=20 \text{ kN}\cdot\text{m}\cdot\text{rad}^{-1}$ but after 280 days loading period this value decreased twice: $K_{\phi}=10 \text{ kN}\cdot\text{m}\cdot\text{rad}^{-1}$. Theoretical investigation results show $K_{\phi}=4 \text{ kN}\cdot\text{m}\cdot\text{rad}^{-1}$ which is two times lower than experiment results.

Conclusions

Experimental test results show that 60% of moment resisting model deformations developed on the first day. For the rest of the testing time, the slower increase of deformations was detected.

It is found to be important existing difference in the composition of an experimental and theoretical model when only bolts as structural members were incorporated without plate and nuts, which are at both sides of the test specimens.

Friction between timber elements was not taken into account in the theoretical investigation, but clearly, it increases the models' stiffness.

The development of deformations in time conforms to a non-linear function. Results show that

two distinctive periods are characteristic in creep development. In the first period till 60 days, an increase of deformations becomes more intensive, but during the rest of the test time the creep development is lower and more sensitive to environmental conditions.

Numerical analysis showed that vertical movement at a lower point of L-type model was approximately two times bigger than the average experimental test results after 280 days of loading.

Also, experimental test results of L-type models showed that average rotational stiffness is $K_{\phi}=20 \text{ kN}\cdot\text{m}\cdot\text{rad}^{-1}$, but after 280 days of loading period rigidity decreased by two times due to creep effects ($K_{\phi}=10 \text{ kN}\cdot\text{m}\cdot\text{rad}^{-1}$). Theoretical investigation shows $K_{\phi}=4 \text{ kN}\cdot\text{m}\cdot\text{rad}^{-1}$

It is important to investigate the development of deformations in time simulating the knee joint of the timber portal frame to gain the best knowledge about the behavior of dowelled moment connections. Investigation showed that theoretical and practical test results are different. To gain a more adequate numerical model, the friction needs to be determined by experimental tests and corresponding ties integrated into the numerical model.

Acknowledgements

Publication and dissemination of research results have been financially supported by the Project of Latvia University of Life Sciences and Technologies: Project Z37 'Methodology for determination of rotational stiffness modulus of moment resisting timber connections'.

References

Awaludin, A., Sasaki, Y., Oikawa, A., Hirai, T., & Hayashikawa, T. (2010). Moment resisting timber joints with high-strength steel dowels: natural fiber reinforcements. In Proceedings of the 11th World Conference on Timber Engineering 2010, WCTE 2010, Vol. 4, 3213–3220. ISBN: 978-162276175-3.

- European committee for standardization (2008). Eurocode 5: Design of timber structures – Part 1-1: General Common rules and rules for buildings. *Proceedings of the ICE – Civil Engineering*. DOI: 10.1680/cien.2001.144.6.39.
- Fokkens, T.J.H. (2017). Behaviour timber moment connections with dowel-type fasteners reinforced with self-tapping screws in seismic areas. THESIS. Eindhoven University of Technology.
- Hanhijärvi, A. (2000). Computational method for predicting the long-term performance of timber beams in variable climates, *Materials and Structures*, No 226, Vol. 33, March 2000, pp. 127–134.
- Leichti, R.J., Hyde, R.A., French, M.L., & Camillos, S.G. (2000). The continuum of connection rigidity in timber structures. *Wood and Fiber Science*, Vol. 32, Issue 1, January 2000, 11–19. ISSN: 07356161.
- Ormarsson, S., Dahlblom, O., & Nygaard, M.J. (2010). Finite element simulation of mechanical and moisture-related stresses in laterally loaded multi-dowel timber connections. In *Proceedings of the 11th World Conference on Timber Engineering 2010, WCTE 2010*, Vol. 4, 3213–3220. ISBN: 978-162276175-3.
- Ozola, L., & Fabriciuss, J. (2019). Assessment of Semi-Rigidity of Dowel Type Knee Joint between Timber Elements, *IOP Conference Series: Materials Science and Engineering – Vol. 471, 4th World Multidisciplinary Civil Engineering, Architecture, Urban Planning Symposium (WMCAUS 2018), 052073 – ISSN 1757-899X*.
- Porteous, J., & Kermani, A. (2013). *Structural timber design to Eurocode 5*. Chichester, West Sussex, UK: John Wiley & Sons Inc.
- Schweigler, M., Bader, T.K., & Hochreiner, G. (2018). Engineering modeling of semi-rigid joints with dowel-type fasteners for nonlinear analysis of timber structures. *Engineering Structures*, 171, 123–139. DOI: 10.1016/J.ENGSTRUCT.2018.05.063.
- Timber Engineering (1995). Step 1. Edited by H.J. Blaß, P. Aune, B.S. Choo, R. Görlacher, D.R. Griffiths, B.O. Hilson, P. Racher, G. Steck. Netherlands: Centrum Hout.
- Hunt, D.G. (1999). A unified Approach to Creep of Wood. *Proceedings of The Royal Society*, No. 455, pp. 4077–4095.

THE ASSESSMENT OF CHEMICAL AND ECOLOGICAL STATUS IN THE WATER BODIES OF SLOCENE AND AGE

***Kristīne Ikauniece, Ainis Lagzdīņš**

Latvia University of Life Sciences and Technologies, Latvia

*Corresponding author's email: kristine.ikauniece@inbox.lv

Abstract

Small rivers are important in terms of water quantity and quality as these rivers collect and deliver water to medium and large rivers downstream. Due to low water flow and high connectivity to adjacent land, small rivers are highly vulnerable to changes caused by natural and anthropogenic factors. This paper aims to assess the chemical and ecological quality of two small rivers including the Slocene and Age as related to dominant land use cover in the contributing area of these water bodies. The effects of land-use patterns and concentrations of chemical substances TN, NO_3^- -N, NH_4^+ -N, TP and PO_4^{2-} -P in river waters will be determined. The highest concentration of total nitrogen (TN) as measured in the Slocene river was 21 mg L^{-1} in spring, while the lowest concentration of TN was 0.86 mg L^{-1} in autumn. The highest concentration of total phosphorus (TP) in the Slocene river was 0.14 mg L^{-1} in late summer, the lowest was 0.03 mg L^{-1} in late autumn. Similarly, in the Age river, the highest concentration of TN was 4.90 mg L^{-1} in spring, while TN the lowest concentration of TN was 0.51 mg L^{-1} in late autumn. The highest concentration of TP in the Age river was 0.3 mg L^{-1} in summer, while the lowest 0.05 mg L^{-1} in autumn.

Key words: agricultural land, forests, chemical and ecological status, nitrogen, phosphorus.

Introduction

An important component of surface waters is small rivers, the amount of which in Latvia is about 6% of the total number of river streams (Apsīte, 2018). According to the national river classification system, these rivers are up to 100 km in length. Rivers of this type are the most vulnerable and susceptible to changes in environmental conditions and anthropogenic activities. Poorly managed anthropogenic activities near small rivers may deteriorate the quality of water ecosystems. Large inputs of plant nutrients from agricultural land improves water fertility coursing increased the growth of algae in both inland and seawaters (Nixon, 1995; Kļaviņš & Sprīņģe, 2011; Voss *et al.*, 2011). Agriculture alone contributes about 80% of the total diffuse load of nitrogen to the Baltic Sea (HELCOM, 2009; Voss *et al.*, 2011).

The smallest particles of soil are colloids, which define the extent and quality of physico-chemical processes in the soil. Soils with relatively high positively charged colloids exhibit more active exchange reactions with the anions of the chemicals in the fertilizers (Nikodemus *et al.*, 2008). Plants can take up to 30–50% of used chemical fertilizers, the remaining part of applied chemicals stay in the soil until it flows away in runoff processes (Mozner, Andrea, & Csutora, 2012). The following forms of nitrogen and phosphorus are considered as nutrients in waters – nitrogen in inorganic ions (NH_4^+ , NO_2^- , NO_3^-) and organic compounds of nitrogen, phosphorus in inorganic ions (PO_4^{3-} , HPO_4^{2-} , H_2PO_4^- ; polyphosphates) and organic compounds of phosphorus (Kļaviņš & Cimdiņš, 2004). In the best case, the plants will use 50% of the total amount of fertilizer applied on the soil, 2–20% will be lost in evaporation processes, 15–25% will interact with the clay particles and last 2–10% will enter surface waters (Savci, 2012).

According to soil characteristics and climatic conditions, relatively high amounts of nitrogen are converted into nitrates due to nitrification processes in the soil. Negatively charged nitrate ions are poorly adsorbed to the soil particles, they remain in the soil solution and are flushed away, for example during heavy rainfalls (Nikodemus *et al.*, 2008). Most soils have a high phosphorus binding capacity, so phosphorus leaching from the soil is low in most cases. Up to 90% of the phosphorus is in the form of organic compounds or can be bound to the suspended particles. Phosphorus is transported in dissolved or particulate form. In the form of suspended particles, it is subjected to the water flow and forms the most part of the phosphorus leakage from arable land (Kļaviņš & Cimdiņš, 2004; Nikodemus *et al.*, 2008). The influx of pollutants is determined by the turbidity of the substances accumulated in the sediment phase and by the surface runoff from agricultural areas. In autumn, the amount of nutrients is influenced by surface runoff and decomposition of organic matter in the body of water itself (Kļaviņš & Cimdiņš, 2004).

Leaching of nitrates and phosphates is an endless process, the second most important cause of diffuse pollution is leaching of organic matter from forest areas which is intensified by cutting down and draining forested areas (Latvijas Vides, ģeoloģijas..., 2009). Small discharges from manure storage and dairies, dry toilets, silos and septic tanks are also considered as diffuse pollution (Latvijas Vides, ģeoloģijas..., 2015a).

The chemical contamination of waters with nutrients are characterized by the presence of nitrogen compounds such as total nitrogen (TN), nitrate-nitrogen (NO_3^- -N), and ammonium nitrogen (NH_4^+ -N), and presence of phosphorus compounds such as total phosphorus (TP) and orthophosphate phosphorus (PO_4^{2-} -P) (Kļaviņš & Cimdiņš, 2004;

Havlin *et al.*, 2005). In clean waters, TN varies from 0.1 to 0.5 mg L⁻¹, concentrations above 1 mg L⁻¹ indicate anthropogenic pollution. TN is also used as an indicator of the degree of eutrophication in the seas (Nixon, 1995; Kļaviņš & Cimdiņš, 2004; Kļaviņš & Sprinģe, 2011). Total phosphorus is a good indicator of the anthropogenic impact on water quality (Nixon, 1995; Kļaviņš & Cimdiņš, 2004). For low-impact waters, the concentration of TP is less than 0.05 mg L⁻¹. TP is also used as an indicator of the degree of eutrophication in lakes (Nixon, 1995; Kļaviņš & Cimdiņš, 2004; Kļaviņš & Sprinģe, 2011). The main objective of this paper is to assess the chemical and ecological quality of two small rivers located in different regions in Latvia with specific hydrological conditions and land use.

Materials and Methods

The selected rivers of Slocene and Age are located in different parts of Latvia, representing regions with similar climate, but different meteorological conditions, soil texture and farming intensity. All Latvian rivers are divided into six types by its length, river basin area and flow rate (Cabinet of Ministers, 2004).

The Slocene River is a moderate type ritral river (Latvijas Vides, ģeoloģijas..., 2015a) located in the northwestern part of Latvia. The soil texture within the river basin mainly is sandy loam (Nikodemus *et al.*, 2008). The farming in this catchment is moderately intensive, 82.3 km² of the total river basin area is agricultural land (European Environment Agency, 2018). According to Latvijas Vides, ģeoloģijas..., 2005 the average TN concentration in this river is 3.5–4.5 mg L⁻¹ which is rated as being high, but TP is >0.18 mg L⁻¹ rated as very high.

The Age River is a moderate type ritral river (Latvijas Vides, ģeoloģijas..., 2015b) situated in the

northeastern part of Latvia. The soil texture within river basin mainly is sandy clay (Nikodemus *et al.*, 2008). The farming in this river basin is moderately intensive, 95.5 km² of the total river basin area is agricultural land (European Environment Agency, 2018). The average TN concentration is 1.5–2.5 mg L⁻¹ rated as moderate, but TP is <0.06 mg L⁻¹ rated as very low (Latvijas Vides, ģeoloģijas..., 2005). Main characteristics of the selected rivers are compiled in Table 1.

Both rivers are moderately deep with a stream speed of >0.2 m s⁻¹. The bottom substrate is formed from sand, gravel and stones (Latvijas Vides, ģeoloģijas..., 2015a, 2015b).

The main diffuse pollution sources are agriculture and background pollution from forests. The Corine Land Cover 2018 database (European Environment Agency, 2018) information is used to obtain the basic data for evaluation. According to the information summarized, a specific area of agricultural land and forested land in each water body is expressed as a parameter relative to the total area of the water body. The calculated percentage of agricultural land and forests is converted into points where high quality is 1 point, good quality is 2 points, medium quality is 3 points, poor quality is 4 points and very poor quality is 5 points (Latvijas Vides, ģeoloģijas..., 2015a, 2015b). The assessment values are developed for each river type, values for assessment of ecological status in moderate ritral rivers are shown in Table 2.

The concentrations of TN, NO₃⁻-N, NH₄⁺-N, TP and PO₄²⁻-P in river waters were analyzed. Samples in the river were taken between 2007 and 2018 with various intervals. Water samples were filled into 1.5 L pure plastic bottles and delivered to the Latvia Environment, Geology and Meteorology Centre laboratory for analysis. TN concentrations were determined by the LVS EN 12260:2004 method

Table 1

Main characteristics of the selected rivers
(Latvijas Vides, ģeoloģijas..., 2015a; 2015b; European Environment Agency, 2018)

River	Type	Length, km	Total catchment area, km ²
Slocene	Moderate ritral	49.05	241.7
Age	Moderate ritral	40.33	202.03

Table 2

Values for assessment of ecological status in moderate ritral rivers
(Latvijas Vides, ģeoloģijas..., 2015a, 2015b)

	High	Good	Medium	Poor	Very poor
Agricultural area	<0.089	0.089–0.240	0.240–0.391	0.391–0.441	>0.441
Forests	<1.416	1.416–1.544	1.544–1.673	1.673–1.801	>1.801

(Latvian Standard, 2004a), $\text{NO}_3\text{-N}$ concentrations were determined by the LVS EN ISO 13395:2004 method (Latvian Standard, 2004b), $\text{NH}_4^+\text{-N}$ concentrations were determined by the LVS EN ISO 11732:2005 method (Latvian Standard, 2005a), TP and $\text{PO}_4^{2-}\text{-P}$ concentrations were determined by the LVS EN ISO 6878:2005 method (Latvian Standard, 2005b).

To assess the importance of diffuse pollution sources the basic data on the distribution of agricultural land and forests in each water body was calculated. To compare data statistically, the analysis of one-factor linear regression was conducted. Changes in the concentrations of nitrogen and phosphorus compounds depending on the sampling time are considered significant ($p \leq 0.05$) if the concentrations of leached chemical compounds increase in spring and autumn but decrease in summer and winter.

The assessment of the water quality of the Age and Slocene rivers has been made according to Water Framework Directive 2000/60/EC and the Nitrate Directive 91/676/EEC instructions and threshold values for surface water body water quality assessment, which in Latvia are integrated into CM Regulation No.118 'Regulation of quality of surface water and groundwater'.

Results and Discussion

Latvia is located in a humid climate zone with mild weather conditions, where rainfalls exceed evaporation and excess water drains into watercourses (Jansons *et al.*, 2003). The specific runoff of a river is affected by the amount of rainfall at each location over the given period of time (Randall & Mulla, 2001; Iital, 2005). The annual precipitation rate in the northwestern part of the Venta River basin district is 650–700 mm, but in the northeastern part of the Gauja River basin

district is 700–750 mm (Latvijas Vides, ģeoloģijas..., 2015a, 2015b). The maximum amount of precipitation is measured in August, while minimum in February. According to water body specific precipitation rates, the annual runoff in the Slocene River is 220 mm, while in the Age River 280 mm (Latvijas Vides, ģeoloģijas..., 2015a, 2015b). The runoff differences between the selected research sites strongly depend on the amount of precipitation. It has been found that runoff from subsurface drainage is the main nutrient transport route from soil profiles to streams – therefore, for analyzing nutrient concentrations in water, the climatic and hydrological conditions of the research site must be taken into account (Randall & Mulla, 2001; Iital, 2005).

In order to determine which sources of diffuse pollution are significant, there is a need to assess whether the values of the land use characterizing economic activities are not close to the limit values above which the ecological quality of water bodies is deteriorating. In the current intensity of economic activity in Latvia, the most significant diffuse pollution loads are characterized by the proportion of agricultural land and forests in the water body (Latvijas Vides, ģeoloģijas..., 2015a).

The total catchment area of the Slocene River basin is 241.8 km², main land-use types are artificial surfaces, agricultural areas, forests, wetlands and water bodies (Figure 1). Agricultural lands of the Slocene River consists of non-irrigated arable land, fruit trees and berry plantations, pastures, complex cultivation patterns and land principally used in agriculture, which is about 34.5% of the total catchment area. Near the Slocene River broad-leaved, coniferous, mixed forests, natural grasslands and transitional woodland shrubs are growing, which is about 48.8%

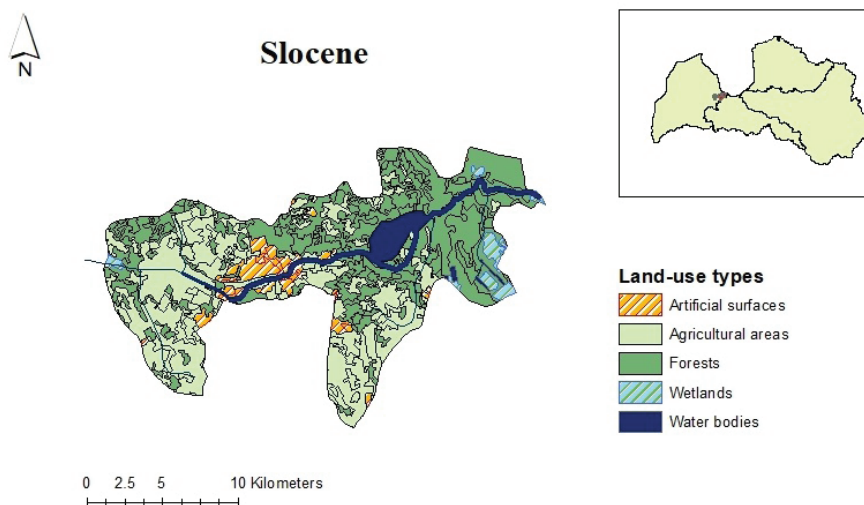


Figure 1. Land use in the Slocene River basin.

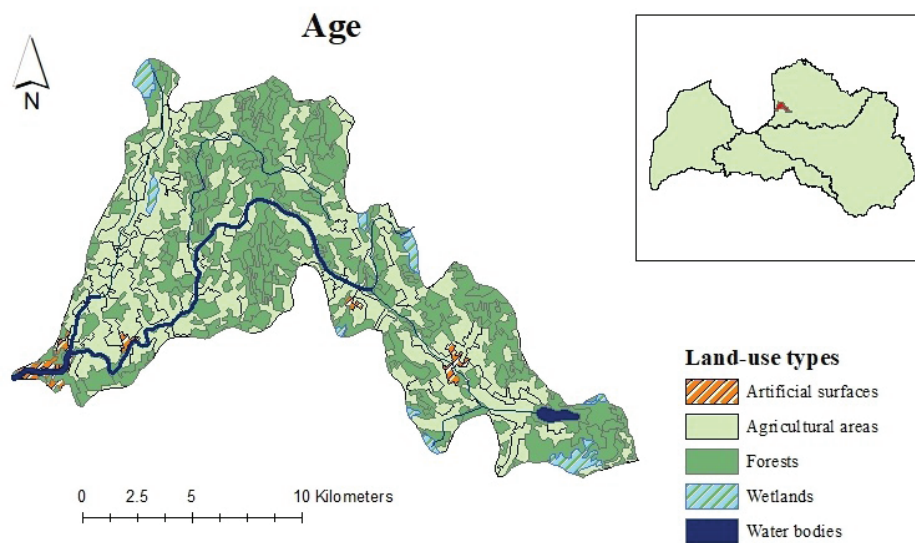


Figure 2. Land use in the Age River basin.

Table 3

Main land use types of the Slocene and Age River basins

River	Total catchment area, km ²	Agricultural area, km ²	Forests, km ²
Slocene	241.8	83.3	118.08
Age	202.03	95.5	96.96

of the total catchment area (European Environment Agency, 2018).

The total catchment area of the Age River basin is 202.03 km², main land-use types are artificial surfaces, agricultural areas, forests, wetlands and water bodies (Figure 2). Agricultural lands of the Age River consists of non-irrigated arable land, pastures, complex cultivation patterns and land principally used in agriculture, which is about 47.3% of the total catchment area (European Environment Agency, 2018). Total catchment area, agriculture land and forest occupied area of the selected river basins are compiled in Table 3.

According to the methodology for the assessment of ecological status, the water quality in the Slocene river basin is evaluated as good, while in the Age River

basin as very poor. In both river basins leaching risks of nutrients are high (Latvijas Vides, ģeoloģijas..., 2005), but a larger share of agricultural land in the Age River basin reflects lower ecological level of the river basin. According to the assessment of ecological status forests in both river basins have a high-quality class. This is due to the relatively large and unmodified forested areas. In the Venta River basin district, 20% of the total forest area is covered with forests, which have been drained to improve forest growth conditions and increase productivity (Latvijas Vides, ģeoloģijas..., 2015a). The same situation applies to the Gauja River basin district, where 60% of the land is covered with forests (Latvijas Vides, ģeoloģijas..., 2015b). The ecological status in both river basins is decreasing by the size of agricultural lands relative to the total

Table 4

Assessment of Ecological status for the Slocene and Age Rivers

Basin district	River	Agricultural land		Forests	
		Relation	Value	Relation	Value
Venta	Slocene	0.34	3	0.48	1
Gauja	Age	0.47	6	0.47	1

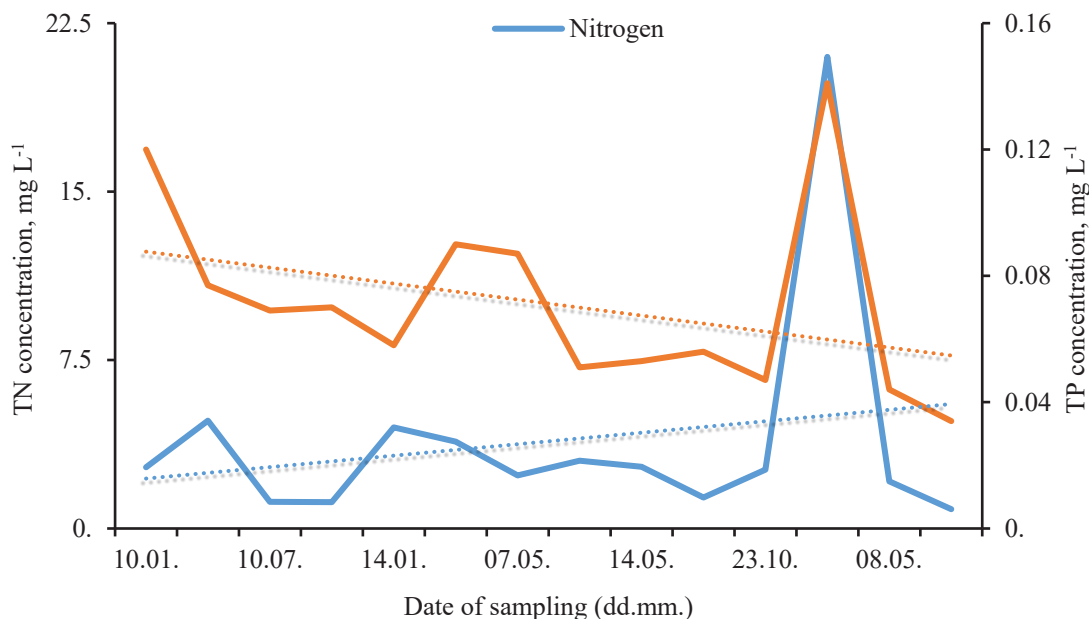


Figure 3. Total nitrogen and phosphorus concentrations in the Slocene River.

catchment area. Assessment of ecological status for the Slocene and Age rivers is shown in Table 4.

The changes in nutrient concentrations over time correlate with hydrological conditions. In both water bodies, the highest concentrations of nutrients were found in early spring and late autumn. In the Slocene river, the highest concentration of TN was 21 mg L⁻¹ in spring, while the lowest concentration of 0.86 mg L⁻¹ in autumn. The highest concentration of TP in the Slocene River was 0.14 mg L⁻¹ in late summer, but the lowest of 0.03 mg L⁻¹ in late autumn (Figure 3).

Similarly in the Age River, the highest concentration of TN was 4.90 mg L⁻¹ in spring, while the lowest of 0.51 mg L⁻¹ – in late autumn. The highest concentration of TP in the Age River was 0.3 mg L⁻¹ in summer, but the lowest 0.05 mg L⁻¹ – in autumn (Figure 4). Summary of nutrient concentrations in the selected rivers is shown in Table 5.

A linear regression analysis of TN and TP concentrations as shown in Figure 3 and 4 indicate that over time the concentrations of TN decrease for the Age River and increase for the Slocene River.

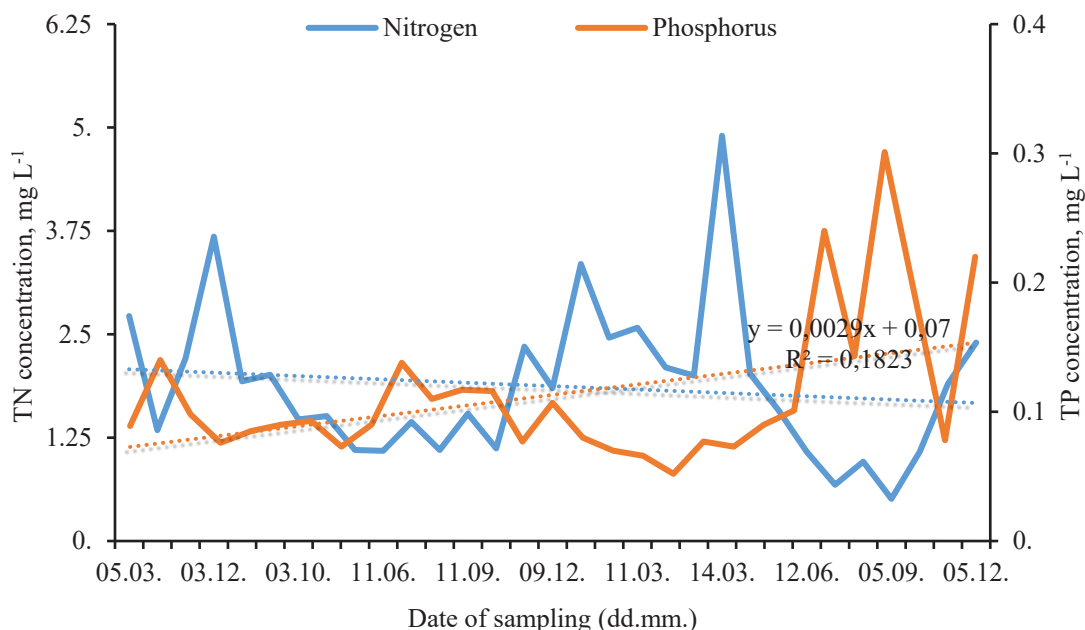


Figure 4. Total nitrogen and phosphorus concentrations in the Age River.

Table 5

Nutrient concentrations in the selected rivers

Parameter	Samples	Values, mg L ⁻¹			Standard Deviation	Sample variance
		Min	Max	Mean		
The Slocene river						
TN	14	0.86	21	3.88	5.07	25.74
NO ₃ ⁻ -N	14	0.28	17.30	2.70	4.32	18.64
NH ₄ ⁺ -N	14	0.05	0.28	0.15	0.07	0.005
TP	14	0.03	0.14	0.07	0.01	0.0001
PO ₄ ²⁻ -P	14	0.01	0.05	0.02	0.03	0.0009
The Age river						
TN	31	0.51	4.90	1.87	0.92	0.85
NO ₃ ⁻ -N	31	0.09	2.90	0.94	0.67	0.45
NH ₄ ⁺ -N	31	0.004	0.38	0.08	0.08	0.0057
TP	28	0.05	0.30	0.11	0.06	0.003
PO ₄ ²⁻ -P	28	0.02	0.16	0.06	0.038	0.0014

In the case of TP concentrations, time trends are opposite, the concentrations increase and decrease for the Age River and Slocene River, respectively. Nutrient concentrations in rivers are characterized by seasonal variability. There is an increase in nutrient concentrations during spring floods and to lesser extents in autumn floods.

The model proposed by the authors is unsuccessful, all except the Age River model TN $p=0.048$ with a level of confidence 95%, is not relevant $p>0.05$. The date and month of analysis do not explain the levels of nutrient concentrations in the rivers. There is lack of information on the amount of precipitation and fertilizer amount in river basin areas, the temperature, etc.

Although the ecological status in the Age River is very poor, the annual mean concentrations of TN in the Age River is above-average values of TN concentrations of 1.5–2.5 mg L⁻¹ (Latvijas Vides, ģeoloģijas..., 2005). Depending on the soil type, the Age River basin agricultural land is less fertilized, 30.5 kg of nitrogen and 1.98 kg of phosphorus per 1 hectare of land are released in the Gauja River basin per year (Latvijas Vides, ģeoloģijas..., 2015b). According to Latvian Environment, Geology and Meteorology Centre, 34.8 kg of nitrogen and 2.69 kg of phosphorus

per 1 hectare of land are released in the Venta River basin per year (Latvijas Vides, ģeoloģijas..., 2015a). Nitrate-nitrogen (NO₃⁻-N) threshold level for good water quality according to the EU Commission (1991) is 11.3 mg L⁻¹ which is equivalent to 50 mg L⁻¹ nitrates (NO₃⁻). This threshold value is not exceeded in the Slocene and Age Rivers with one exception in the Slocene River.

Conclusions

1. The ecological and chemical status of the Slocene and Age rivers depend on number of factors including soil type, climatic conditions, land use types, and anthropogenic activities.
2. The highest concentrations of nutrients have been measured during the spring period. This indicates that snow accumulation during the winter season is rather high in these waterbodies, and snow melt during the spring may cause increased nutrient losses from diffuse sources.
3. There is a need to implement edge-of-field practices such as sedimentation ponds, constructed wetlands, bottom dams, meandering, controlled drainage, and two-stage ditches in the Slocene and Age waterbodies in order to reduce nutrient losses from diffuse sources.

References

Apsīte, E. (2018). Virszemes ūdeņi (Surface waters). In O. Nikodemus (Eds.) *Latvija. Zeme, daba, tauta, valsts. (Latvia. Land, Nature, Nation, Country.)* (pp. 273–321). Rīga, LU Akadēmiskais apgāds (in Latvian).
Cabinet of Ministers. (2004). *Regulation No. 858 Regulations of Characterization, Classification, Quality Criteria of Surface Water Body Types for Determination of Anthropogenic Loads*. Rīga: Latvijas Vēstnesis.
EU Commission. (1991). *Directive 91/676/EEC: The protection of waters against pollution caused by nitrates from agricultural sources*. Brussels: Official Journal of European Community, L 375, 1–8.

- EU Commission. (2000). *Directive 2000/60/EC: Establishing a framework for the Community action in the field of water policy*. Brussels: Official Journal of European Community, L 327, 1–72.
- European Environment Agency. (2018). *Copernicus Land Monitoring Service*. Retrieved February 14, 2020, from <https://www.copernicus.eu/en/services/land>.
- HELCOM. (2009). *Eutrophication in the Baltic Sea – An integrated thematic assessment of the effects of nutrient enrichment and eutrophication in the Baltic Sea region*. Helsinki: Finland, Baltic Sea Environmental Proceedings No. 115B.
- Havlin, J.L., Beaton, J.D., Tisdale, S.L., & Nelson, W.L. (2005). *Soil Fertility and Fertilizers: An Introduction to Nutrient Management* (7th ed.). New Jersey: Pearson Education.
- Iital, A. (2005). *Monitoring of surface water quality in small agricultural watersheds*. Doctoral dissertation, Tallinn University of Technology, Estonia.
- Jansons, V., Busmanis, P., Dzalbe, I., & KIRSTEINA, D. (2003). Catchment and drainage field nitrogen balances and nitrogen loss in three agriculturally influenced Latvian watersheds. *European Journal of Agronomy*, 20 (1–2), 173–179. DOI: 10.1016/S1161-0301(03)00072-8.
- Kļaviņš, M., & Cimdiņš, P. (2004). *Ūdeņu kvalitāte un tās aizsardzība (Water Quality and its Protection)*. (pp. 49–54). Rīga: Latvia University (in Latvian).
- Kļaviņš, M., & Sprinģe, G. (2011). *Vides piesārņojums (Environmental Pollution)*. In M. Kļaviņš & J. Zaļoksnis (Eds.) *Vide un ilgtspējīga attīstība (Environment and Sustainable Development)*. (pp. 87–106). Rīga, LU Akadēmiskais apgāds (in Latvian).
- Latvijas Vides, ģeoloģijas un meteoroloģijas aģentūra. (2005). *Upju baseinu apgabalu raksturojums, antropogēno slodžu uz pazemes un virszemes ūdeņiem novērtējums, ekonomiskā analīze (Characteristics of river basin districts, assessment of anthropogenic pressures on groundwater and surface water, economic analysis)*. Rīga: Ministry of Environment (in Latvian).
- Latvijas Vides, ģeoloģijas un meteoroloģijas centrs. (2009). *Izkliedētais piesārņojums (Diffuse pollution). Ventas upju baseinu apgabala apsaimniekošanas plāns 2010–2015. gadam (The Venta River basin district management plan for 2010–2015)*. (pp. 11–12). Rīga (in Latvian).
- Latvijas Vides, ģeoloģijas un meteoroloģijas centrs. (2015a). *Ventas upju baseina apsaimniekošanas plāns 2016–2021.gadam (The Venta River basin district management plan for 2016–2021)*. (pp. 22–48). Rīga (in Latvian).
- Latvijas Vides, ģeoloģijas un meteoroloģijas centrs. (2015b). *Gaujas upju baseina apsaimniekošanas plāns 2016–2021.gadam (The Gauja River basin district management plan for 2016–2021)*. (pp. 20–41). Rīga (in Latvian).
- Mozner, Z., Andrea, T., & Csutora, M. (2012). Modifying the yield factor based on more efficient use of fertilizer—The environmental impacts of intensive and extensive agricultural practices. *Ecological Indicators*, 16, 58–66. DOI: 10.1016/j.ecolind.2011.06.034.
- Nikodemus, O., Kārklīšs, A., Kļaviņš, M., & Meleciš, V. (2008). *Augsnes ilgtspējīga izmantošana un aizsardzība (Sustainable Use and Protection of Soil)*. Rīga, LU Akadēmiskais apgāds (in Latvian).
- Nixon, S.W. (1995). Coastal marine eutrophication: a definition, social causes and future concerns *Ophelia*, 41, 199–219.
- Randall, G.W., & Mulla, D.J. (2001). Nitrate nitrogen in surface waters as influenced by climatic conditions and agricultural practices. *Journal of Environment Quality*, 30, 337–344. DOI: 10.2134/jeq2001.302337x.
- Savci, S. (2012). An Agricultural Pollutant: Chemical Fertilizer. *International Journal of Environmental Science and Development*, 3, 77–79. DOI: 10.7763/IJESD.2012.V3.191.
- Latvian Standard. (2004a). Latvian standard: Water quality: determination of nitrogen. LVS EN 12260:2004. Rīga.
- Latvian Standard. (2004b). Latvian standard: Water quality: Spectrometric determination of nitrate nitrogen and total saturation by flow analysis. LVS EN ISO 13395:2004. Rīga.
- Latvian Standard. (2005a). Latvian standard: Water quality: Ammonium nitrogen determination. the LVS EN ISO 11732:2005. Rīga.
- Latvian Standard. (2005b). Latvian standard: Water quality: Determination of phosphorus. LVS EN ISO 6878:2005. Rīga.
- Voss, M., Dippner, J.W., Humborg, C., Hürdler, J., Korth, F., Neumann, T., Schernewski, G., & Venohr, M. (2011). History and scenarios of future development of Baltic Sea eutrophication. *Estuarine, Coastal and Shelf Science Journal*, 92, 307–322. DOI: 10.1016/j.ecss.2010.12.037.

IMPACT OF THE USE OF EXISTING DITCH VECTOR DATA ON SOIL MOISTURE PREDICTIONS

*Janis Ivanovs, Toms Stals, Santa Kaleja

Latvian State Forest Research Institute 'Silava', Latvia

*Corresponding author's email: janis.ivanovs@silava.lv

Abstract

Wet soils play an important role in hydrological, biological and chemical processes, and knowledge on their spatial distribution is essential in forestry, agriculture and similar fields. Digital elevation models (DEM) and various hydrological indexes are used to perform water runoff and accumulation processes. The prerequisite for the calculation of the hydrological indexes is the most accurate representation of the Earth's surface in the DEM, which must be corrected as necessary to remove surface artifacts that create a dam effect. In addition, different resolutions for DEM give different results, so it is necessary to evaluate what resolution data is needed for a particular study. The aim of this study is to evaluate the feasibility of using existing ditch vector data for DEM correction and the resulting implications for soil moisture prediction. Applied methodology uses a network of available ditch vectors and creates gaps in the overlapping parts of the DEM. The data were processed using open source GIS software QGIS, GRASS GIS and Whitebox GAT. Ditch vector data were obtained from JSC Latvian State Forests and the Latvian Geospatial Information Agency. The results show that by applying the bottomless ditch approach in forest lands on moraine deposits, depending on the accuracy of the ditch vector data, the values of the prediction of the soil wetness both increase and decrease. On the other hand, in forest lands on glaciolimnic sediments it is visible that predicted soil wetness values increase in the close proximity of ditches. For forest lands on glaciofluvial and eolitic sediments there were no visible changes because of lack of ditches.

Key words: wet area maps, quaternary sediments, LiDAR.

Introduction

Open wetland areas are easily identified and mapped by orthophoto or satellite imagery, but are more difficult to identify in the forest under an enclosed tree canopy or near waterbodies and streams (Creed *et al.*, 2003; Gregory *et al.*, 1991). In Latvia, studies on the spatial distribution of wetland soils in forest lands have begun relatively recently (Ivanovs & Lupikis, 2018) and so far have developed methods for deciphering wetlands on different types of geological sediments. For this purpose LiDAR (Light Detecting and Range) data maintained by the Latvian Geospatial Information Agency and Sentinel-2 multispectral satellites were used.

Information on the spatial distribution of wetlands is important for both scientific and management planning in areas such as forestry and agriculture (McNabb, Startsev, & Nguyen, 2001). This information can help explain biological, hydrological, chemical, and other processes (Detenbeck *et al.*, 1999). Hydromorphic soils have a lower bearing capacity than automorphic soils and are therefore more prone to disturbances such as compaction, rutting, etc. (Cambi *et al.*, 2015; Mohtashami *et al.*, 2017).

Digital terrain models and various hydrological indices are used to perform water runoff and accumulation processes (Robson, Beven, & Neal, 1992). The prerequisite for calculating the hydrological indexes is the most accurate representation of the Earth's surface in the digital terrain model, which needs to be corrected to remove surface artifacts that produce a dam effect (Lidberg *et al.*, 2017). In addition, different resolutions of the DEM (digital elevation

model) give different results, so it is necessary to evaluate what resolution data is needed for a particular study (Dehvari & Heck, 2013).

The aim of the study is to test the performance of the wet area detection algorithm under conditions using existing spatial data from ditches and natural drains. It is assumed that if the water flows to a ditch as a result of surface runoff modeling, it is automatically removed from the system. Improvements for methodology are necessary to avoid manual DEM corrections.

Materials and Methods

The study objects represent all the most popular Quaternary geological sediment types (Glaciolimnic, Gglacigenic, Glaciofluvial and Eolitic) and are dominated by forests on mineral and drained mineral soils. The study objects each cover an area of 9 km², in the central part of which 1 km² is used for the placement of plots. The buffer zone was created for the purpose of modeling the surface water runoff, thereby providing continuous calculation area for larger territory. Quaternary geological sediment data were obtained from the Quaternary sediment map at a scale of 1:200,000 (Meirons, 2002). The geospatial data of the forest stands were obtained from the JSC Latvian State Forests. The location of the research objects is shown in Figure 1. The DEM was obtained using laser scanning data maintained by the Latvian Geospatial Information Agency and the processing of geospatial data was performed in QGIS and GRASS GIS programs.

Digital elevation models were overlaid with existing ditch vector data which are maintained by

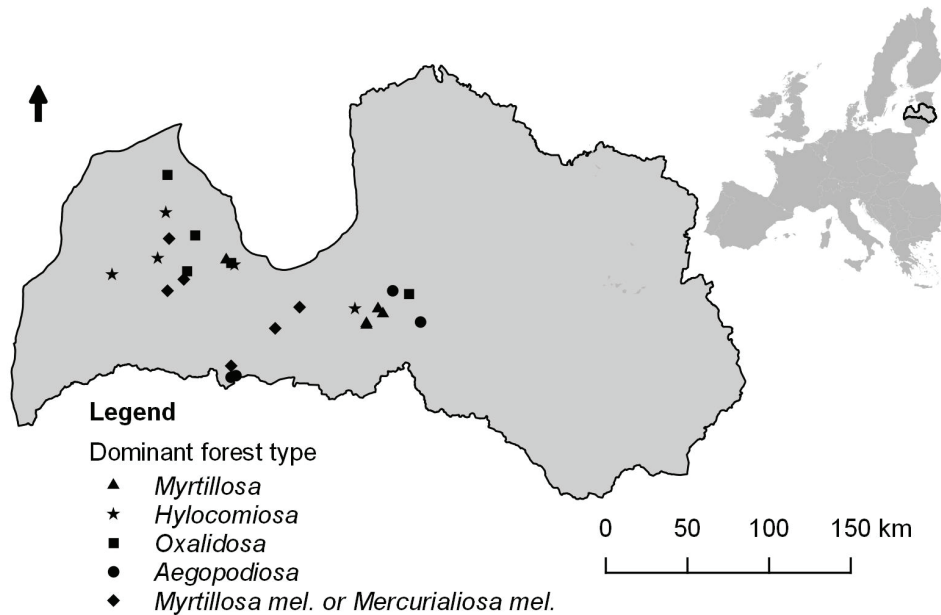


Figure 1. Location of research objects.

JSC Latvian State Forests and Latvian Geospatial Information Agency were thus cutting holes in the relief model. And during surface water runoff modelling on modified DEM's, surplus water was removed from the model through the holes in DEM.

The newly created DEM layers with a horizontal resolution of 2 m have been used to obtain 2 m horizontal resolution models of the surface slope, surface depressions, normalized height and SAGA moisture index data. The obtained indices characterizing the surface of the Earth were used to produce maps of soil moisture predictions based on previous research (Ivanovs & Lupikis, 2018) and following formula:

$$\begin{aligned}
 & \text{if}(N = GL \text{ or } N = H, (\exp(2.522 - 1.226 * \\
 & S_{5m} - 5.012 * NH_{2m}))/(\exp(2.522 - 1.226 * \\
 & S_{5m} - 5.012 * NH_{2m}) + 1), (\text{if}(N = \\
 & G(\exp(48.749 * D_{2m} - 3.645))/(\exp(48.749 * \\
 & D_{2m} - 3.645) + 1), (\text{if}(N = GF, (\exp(32.95 - \\
 & 2.788 * W_{2m} - 63.565 * NH_{5m} - 2.387 * \\
 & S_{5m}))/(\exp(32.95 - 2.788 * W_{2m} - \\
 & 63.565 * NH_{5m} - 2.387 * S_{5m}) + 1), (\text{if}(N = \\
 & E, (\exp(96.576 * NDVI * F - 93.506 - 2.437 * \\
 & NH_{m2} + 1.651 * W_{2m}))/(\exp(96.576 * \\
 & NDVI * F - 93.506 - 2.437 * NH_{m2} + 1.651 * \\
 & W_{2m}) + 1), 1/0)))))) ,
 \end{aligned}
 \tag{1}$$

where N – Quaternary sediment raster, G – Glacigenic sediments, GL – Glaciolimnic sediments, GF – Glaciofluvial sediments, E – Eolitic sediments, H – Organic sediments, S – raster of slope, D – raster of depressions, NH – normalized height raster, W – Saga wetness index, F – Forest cover (1 or null). Numbers by indices show necessary resolution.

To compare the results with and without effect of using existing ditch vector data, the soil moisture prediction rasters were compared with each other using raster calculator. Thus, resulted rasters indicate differences between both methods (Figure 2). Raster values leaning towards -1 indicate that prediction for the area is more wet than predicted using previous methodology and for values that are leaning towards +1 it's getting dry. The obtained results were compared by creating raster histograms. Raster data is presented as input data, which shows differences in predictions. The generated histograms are plotted on a logarithmic scale and indicate the number of cells that are leaning to one side or the other, predicting drier or wetter conditions, respectively.

Results and Discussion

The areas on the glacial, or moraine sediments have both areas where drier and wetter areas are formed according to the methodology tested in this study (Figure 2). In the close proximity of the ditches, soil wetness values have declined due to the elimination of local depressions. However, the soil wetness prediction values have increased in some areas and that may be due to a shift in the ditch vectors' locations relative to the location of the ditches in the LiDAR data or other conditions. A comparison picture of the results of the various methods gives a visual indication of the 'noise' around the wet areas. This noise is due to data processing in the preparation of input raster and resulted in a slight shift in wet areas.

The results for areas that represent the situation on glaciolimnic sediments are shown in Figure 3. It can be seen that, when ditch vector data is used for DEM

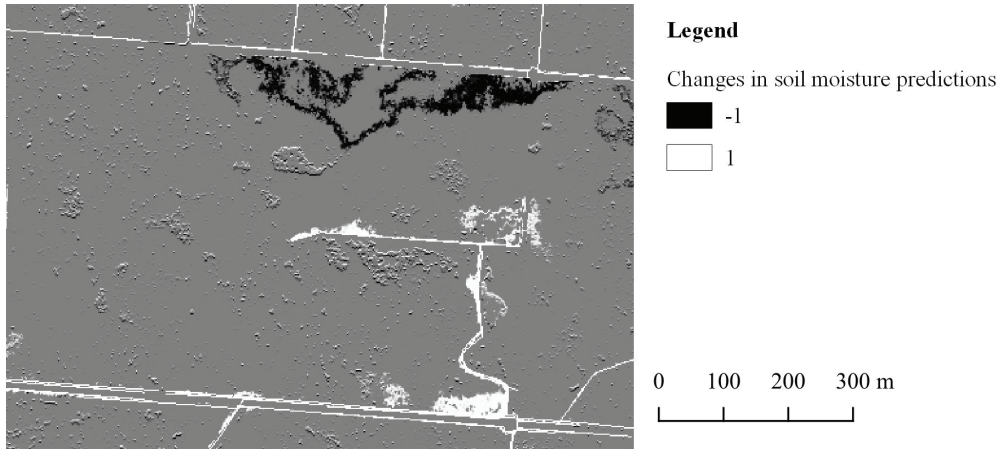


Figure 2. Soil wetness prediction changes on glacial sediments.

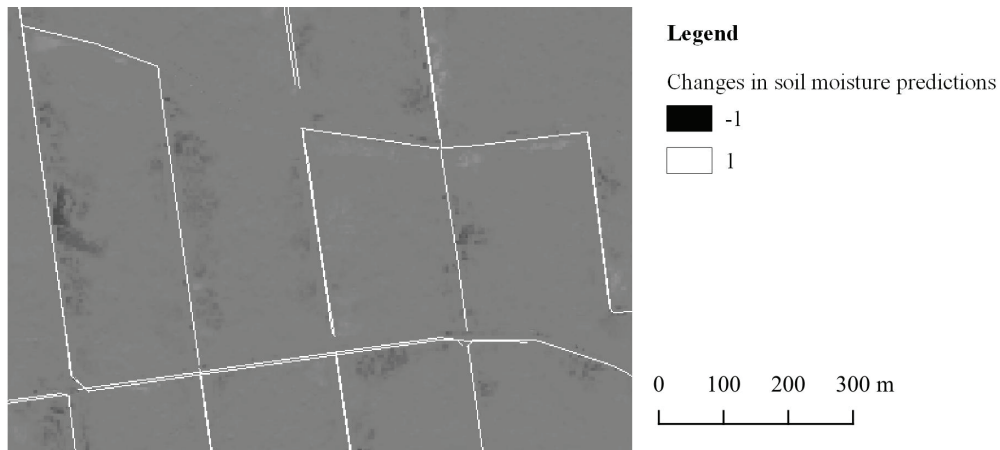


Figure 3. Soil wetness prediction changes on glaciolimnic sediments.

correction, higher soil moisture is predicted in areas adjacent to ditches. No changes have been observed in areas further from the ditches. The effect of this ditch proximity is explained by the input raster files that are used to predict soil moisture on glaciolimnic sediments. A significant influence on soil moisture

distribution is coming from normalized height raster, which indicates local elevation changes. By their nature, ditches are considered to be locally lower terrain. If ditch elevation information is removed from the local elevation map, other adjacent areas should become locally lower.

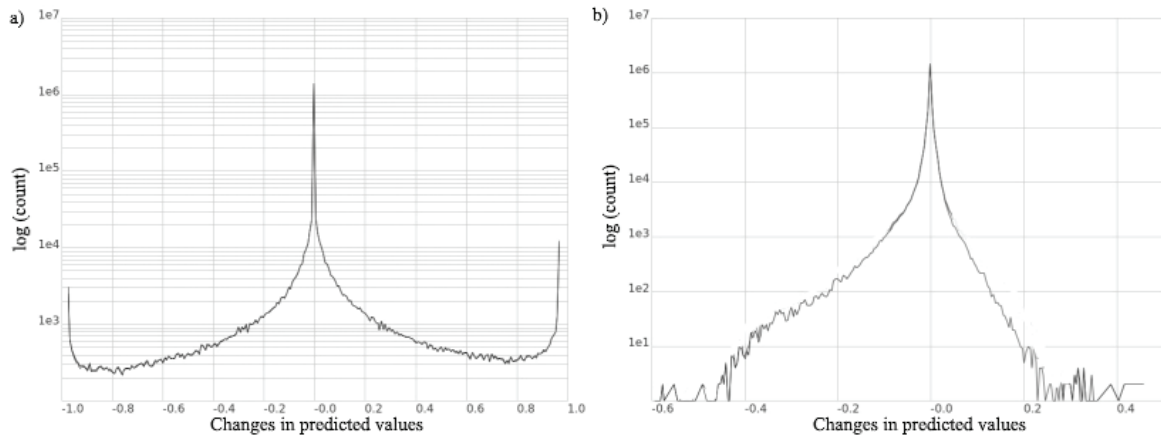


Figure 4. Histograms of changes in soil wetness predictions.

The histograms also show that the methodology used in this study slightly changes the prediction of soil moisture (Figure 4). The absolute majority of values do not change, but a deviation is observed. For areas on glacial sediments, (a) there is a relatively large number of extreme values which indicate significant changes in the soil wetness predictions in one direction or the other. However, for the areas on glaciolimnic (b) sediments, there is a slight shift in predictions towards the wet side.

Conclusions

1. Soil wetness predictions for areas on glacial sediments is significantly influenced by local depressions. By modifying DEM with overlapping ditch vector data and changing elevation values in overlaying areas to *null*, many local depressions are eliminated, thus making soil wetness predictions to dry conditions.

2. For soils on glaciolimnic sediments, soil wetness predictions for the area close to ditches are leaning towards wet conditions, because local lowest elevations are eliminated and thus making other proximate areas as locally wet.
3. In some areas on glacial sediments soil wetness predictions are increasing because of slight horizontal shift between digitized ditch vectors and ditch locations in DEM.
4. There are no differences in soil moisture forecasts using different methodologies in areas with glaciofluvial and aeolian deposits.

Acknowledgements

The study is implemented within the scope of the project Demonstration of climate change mitigation measures in nutrients rich drained organic soils in the Baltic States and Finland LIFE OrgBalt, grant agreement No. LIFE18 CCM/LV/001158.

References

- Cambi, M., Certini, G., Neri, F., & Marchi, E. (2015). The impact of heavy traffic on forest soils: A review. *Forest Ecology and Management*, 338, 124–138. DOI: 10.1016/J.FORECO.2014.11.022.
- Creed, I.F., Sanford, S.E., Beall, F.D., Molot, L.A., & Dillon, P.J. (2003). Cryptic wetlands: integrating hidden wetlands in regression models of the export of dissolved organic carbon from forested landscapes. *Hydrological Processes*, 17(18), 3629–3648. DOI: 10.1002/hyp.1357.
- Dehvari, A., & Heck, R.J. (2013). Effect of LiDAR derived DEM resolution on terrain attributes, stream characterization and watershed delineation. *International Journal of Agriculture and Crop Sciences*, 6(13), 949–967. Retrieved March 10, 2020, from www.ijagcs.com.
- Detenbeck, N.E., Galatowitsch, S.M., Atkinson, J., & Ball, H. (1999). Evaluating perturbations and developing restoration strategies for inland wetlands in the Great Lakes basin. *Wetlands*, 19(4), 789–820. DOI: 10.1007/BF03161785.
- Gregory, S.V., Swanson, F.J., McKee, W.A., & Cummins, K.W. (1991). An Ecosystem Perspective of Riparian Zones. *BioScience*, 41(8), 540–551. DOI: 10.2307/1311607.
- Ivanovs, J., & Lupikis, A. (2018). Identification of wet areas in forest using remote sensing data. *Agronomy Research*, 16. DOI: 10.15159/AR.18.192.
- Lidberg, W., Nilsson, M., Lundmark, T., & Ågren, A.M. (2017). Evaluating preprocessing methods of digital elevation models for hydrological modelling. *Hydrological Processes*, 31(26), 4660–4668. DOI: 10.1002/hyp.11385.
- McNabb, D.H., Startsev, A.D., & Nguyen, H. (2001). Soil Wetness and Traffic Level Effects on Bulk Density and Air-Filled Porosity of Compacted Boreal Forest Soils. *ResearchGate*, 65(4). DOI: 10.2136/sssaj2001.6541238x.
- Meirons, Z. (2002). *Quaternary sediments. M.:1:200 000*. State Geological Survey.
- Mohtashami, S., Eliasson, L., Jansson, G., & Sonesson, J. (2017). Influence of soil type, cartographic depth-to-water, road reinforcement and traffic intensity on rut formation in logging operations: A survey study in Sweden. *Silva Fennica*, 51(5). DOI: 10.14214/sf.2018.
- Robson, A., Beven, K., & Neal, C. (1992). Towards identifying sources of subsurface flow: A comparison of components identified by a physically based runoff model and those determined by chemical mixing techniques. *Hydrological Processes*, 6(2), 199–214. DOI: 10.1002/hyp.3360060208.

DATA FUSION CHALLENGES IN PRECISION BEEKEEPING: A REVIEW

*Nikolajs Bumanis

Latvia University of Life Sciences and Technologies, Latvia

*Corresponding author's email: nikolajs.bumanis@gmail.com

Abstract

The objective of precision beekeeping is to minimize resource consumption and maximize productivity of bees. This is achieved by detecting and predicting beehive states by monitoring apiary and beehive related parameters like temperature, weight, humidity, noise, vibrations, air pollution, wind, precipitation, etc. These parameters are collected as a raw input data by use of multiple different sensory devices, and are often imperfect and require creation of correlation between time data series. Currently, most researches focus on monitoring and processing each parameter separately, whereas combination of multiple parameters produces information that is more sophisticated. Raw input data sets that complement one another could be pre-processed by applying data fusion methods to achieve understanding about global research subject. There are multiple data fusion methods and classification models, distinguished by raw input data type or device usage, whereas sensor related data fusion is called sensor fusion. This paper analyses existing data fusion methods and process in order to identify data fusion challenges and correlate them with precision beekeeping objectives. The research was conducted over a period of 5 months, starting from October, 2019 and was based on analysis and synthesis of scientific literature. The conclusion was made that requirement of data fusion appliance in precision beekeeping is determined by a global research objective, whereas input data introduces main challenges of data and sensor fusion, as its attributes correlate with potential result.

Key words: data fusion methodology, sensor fusion, sensory monitoring, bee colony states, hiveopolis.

Introduction

Precision beekeeping (PB) is an apiary management strategy with the focus on monitoring individual bee colonies aimed to minimize resource consumption and maximize the productivity of bees (Zacepins, Stalidzans, & Meitalovs, 2012). Strategy includes data collection phase, data processing phase and data output phase. Data collection phase corresponds to gathering data about various physical variables associated with bee colonies (Meikle & Holst, 2015), such as temperature, humidity, respiratory gases, vibration and sound. Data collection is typically performed using sensors that are integrated into bee hives and are connected to the main processing system (Kviesis *et al.*, 2015). Processing phase of bee colony data is typically limited to basic statistical analysis (Henry *et al.*, 2019) with the aim to determine such bee colony states as queenlessness, broodlessness, pre-swarming, swarming and after swarming. Data output phase includes methods to provide processed data – information, to end user in a form of a graphical or tabular representation.

There are multiple studies (Ferrari *et al.*, 2008; Kviesis & Zacepins, 2015; Meikle & Holst, 2015; Zacepins *et al.*, 2015) aimed to identify approaches to gather data for analysis, and also define the types of these data. Some of these studies (Human *et al.*, 2013) also propose classification of data collection phase. The limitation of these studies lies in gathering data for particular physical variables like temperature or weight with the aim to analyse this variable by itself. In modern apiaries data if collected through the use of wireless network technologies (Debauche *et al.*, 2018; Henry *et al.*, 2019), can lead to data imperfections and inconsistency. To alleviate such

problems, data fusion methods are applied prior to data processing.

There are multiple studies (Castanedo, 2013; Khaleghi *et al.*, 2013; Zheng, 2015; Atluri, Karpatne, & Kumar, 2018; Beddar-Wiesing & Bieshaar, 2020) addressing the classification of data fusion methods. However, there is no finalized accepted data fusion classification, and researchers are still proposing new variations.

In the framework of PB, application of data fusion methods can lead to solving global objectives of bee colony lifecycle, such as colony overall health status and colony collapse disorder. However, appliance of data fusion methods in PB is not commonly used practice. The aim of this research was to identify PB oriented data sets and objectives, which can only be achieved by appliance of data fusion methods.

This research was performed in the framework of HIVEOPOLIS project that aims to make technologies available to honeybees that are naturally inaccessible for them (internet, databases, satellite data, robots, etc) and to feed information collected by bees through these channels back to us researchers and also to other hives.

Materials and Methods

The research was conducted over a period of 5 months, starting from October, 2019, and was based on analysis and synthesis of scientific literature, which addresses data fusion terminology, methodology and application, multi sensor monitoring in beekeeping and development of sensory systems to determine various physical apiary oriented variables and states. The Elsevier's ScienceDirect website was used as the main source for literature acquisition. There are

currently (on 13th of March) more than 68000 recent (20017–2020) papers on data fusion topic, more than 43000 papers on multi-sensor data, and more than 450 papers on beekeeping related topics.

Results and Discussion

Data fusion

Recent fusion terminology proposal (Beddar-Wiesing & Bieshaar, 2020) uses data-information-knowledge-wisdom (DIKW) hierarchy as a base to finalize the data fusion oriented terms. In DIKW data is divided (Bellinger, Castro, & Mills, 2003; Allen, 2004; Targowski, 2005) into five categories: data, information, knowledge, understanding and wisdom. Data is described as representation of objects, whereas processed data leads to information, which can provide answers to ‘who’, ‘what’, ‘where’ and ‘when’ questions. The application of these data and information generates knowledge, which can provide an answer to ‘why’ question. If relations and patterns in the information are identified, understanding is reached. As a result, following DIKW hierarchy, I can assume that the quality of data is proportional to the quality of information; therefore, understandability of research object is ensured.

Data fusion as a term is applied to raw data, the first step of DIKW hierarchy. The most accepted definition of data fusion was provided by Joint Directors of Laboratories (JDL) workshop (White, 1991): ‘a process dealing with the association, correlation, and combination of data and information from single and multiple sources to achieve refined position and identity estimates, and complete and timely assessments of situations and threats as well as their significance’. Hall and Llinas (Hall & Llinas, 1997) provided sensor system oriented data fusion definition: ‘data fusion techniques combine data from multiple sensors, and related information from associated databases, to achieve improved accuracies and more specific inferences than could be achieved by the use of a single sensor alone’. The employment of terms data and information in these definitions as separate instances can be explained by applying these terms to different data states. The term data fusion is typical in scenarios when data are raw – obtained directly from sensors, whereas the term information fusion is applied to already processed data (Castanedo, 2013). These definitions support my previous assumption about quality data being determinant for quality of information.

According to Castanedo (Castanedo, 2013), data fusion technologies can be classified into three categories, which are data associations, state estimation and decision fusion. This classification was developed based on such criteria as relations between input data sources, input and output data types

and their nature, and the abstraction levels of data, which are raw measurements, signals or decisions. The relation between data sources is determined by whether the information was provided by data input sources representing the same or different part of the scene and/or object, whereas the abstraction level corresponds to representation of the input data. In PB data input sources are typically imbedded into beehives; therefore, one set of sensors monitors one particular beehive, rather than an apiary. The Luo *et al.* (Luo, Yih, & Su, 2002) proposed such abstraction levels as signal level, pixel level, characteristics level and symbol level.

Alternatively, Zheng (Zheng, 2015) classifies data fusion in three categories, which are feature-level based, stage based and semantic meaning based. Zheng’s stage based data fusion correlates with Castaneda’s state estimation. Both of these methods process raw data according to the amount of distinct data sets in sequence. The amount of distinct data sets, or, in perspective of spatial data – layers, leads to quality increase of end result data; however, each of layers may introduce additional fusion challenges. Feature-level based data fusion methods include converting or mapping raw input data into feature vectors that are used for Deep Neural Network (DNN) type data fusion. Liu *et al.* (Liu *et al.*, 2020) proposed DNN data fusion methods for urban big data with the focus on fusing multi modular data, and Peng *et al.*, (Peng, Deng, & Chen, 2020) used DNN in combination with Hellinger and Bures metrics for weather data fusion. Both of these studies show that raw input data converted into feature vectors highly increase the scope of possible processing approaches. Both decision fusion and semantic meaning based fusion work with knowledge, rather than raw data; therefore, in this research these methods are not analysed in-depth. Based on DWIK and data fusion classification a hypothesis was put forward: data fusion challenges are mainly raw data related.

To understand the importance of raw data the data fusion process was further analysed. The most basic data fusion process, which is still commonly referenced (Solaiman, 1999; Castanedo, 2013; Zheng, 2015; Chang & Bai, 2018), was proposed by JDL workshop (White, 1991). JDL has divided data fusion process into five processing levels, which are level 0 – source preprocessing, level 1 – object refinement, level 2 – situation assessment, level 3 – impact assessment, and level 4 – process refinement. Source preprocessing includes fusion at the signal and pixel levels. Object refinement – includes process as spatial-temporal alignment, association, correlation, clustering, state estimation, combining of features that were extracted from images. Situation assessment addresses evaluation of relations between

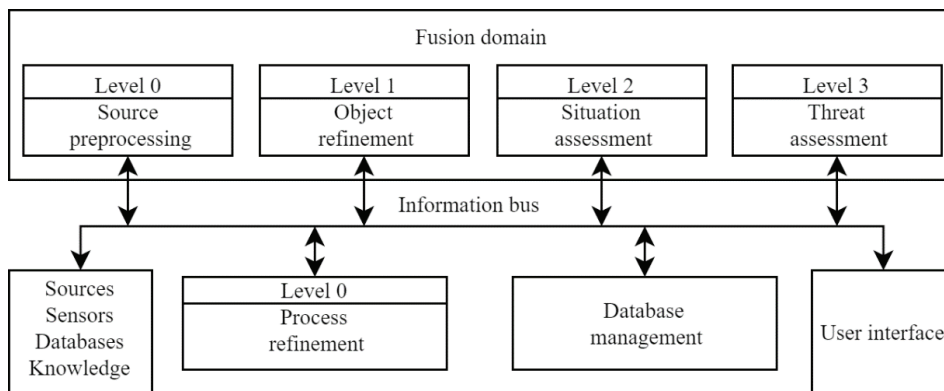


Figure 1. Fusion process according to Joint Directors of Laboratories (Blasch & Plano, 2002; Llinas *et al.*, 2004).

object parameters, i.e. proximity, communication, interference, with the aim to identify activities and patterns. Impact assessment evaluates impact of identified activities to obtain a general perspective, i.e. calculates risks, vulnerabilities and operational opportunities. Process refinement uses results from level 0 to level 3 to optimize efficiency of resource management. Based on JDL fusion process definition, the type of raw data is not an obstacle for data fusion, as processing module can fix and adjust it in the second processing step by various means. This leads to taking a previous stated hypothesis as incorrect; however it may change depending on data fusion challenges.

According to Llinas *et al.* (Llinas *et al.*, 2004) definition of fusion process provided by JDL can only be used as a framework (Figure 1) to understand the functions of data fusion, instead of being taken as a detailed processing architecture.

JDL has many restrictions (Khaleghi *et al.*, 2013) as it is tuned for military applications; however, fusion process can be improved and adjusted, for example, by adding a new level – user refinement (Blasch & Plano, 2002), which delineates a human from the machine in the process refinement. There can also be improvements to existing levels by addressing the following aspects (Llinas *et al.*, 2004): (1) issues related to quality control, reliability and consistency,

(2) opportunities and needs for co-processing and (3) distributed data fusion. Overall, data fusion method is chosen based on volume and properties of available raw data. Therefore, the data aspect of data fusion process is still determinant to the overall result, and challenges regarding raw data collection and pre-processing were analysed.

Data fusion challenges

In the PB the type of raw data is determined by a sensor or third party source; therefore, the data fusion challenges were first analysed from the perspective of data and its related fusion aspects (Figure 2).

It is acknowledged (Khaleghi *et al.*, 2013) that data provided by sensors are always affected by impreciseness and some degree of uncertainty of the measurements, thus introducing data imperfection. Sensors in PB often become affected by the environment (Kumar, Garg, & Zachery, 2006; Henry *et al.*, 2019) introducing outliers into raw data sets. It is common in the field of statistics to remove outliers (Zhang, Meratnia, & Havinga, 2010) prior to performing any analysis and processing.

When using multiple sensors to produce the same physical variable, for example – temperature, conflicting data may be created, thus requiring in-depth pre-processing procedures to eliminate such occurrences. In the case of multi sensor systems

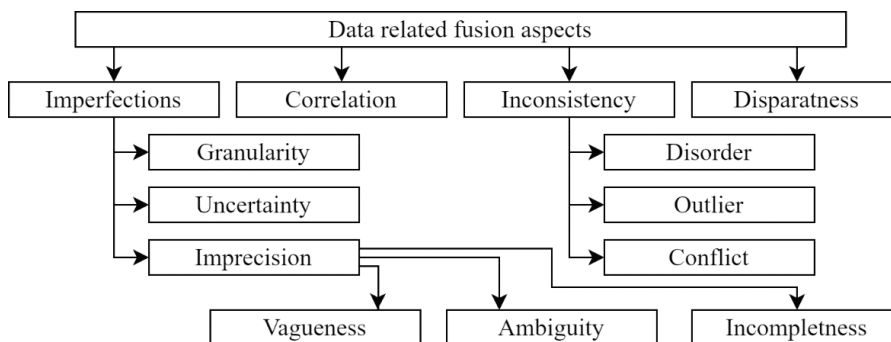


Figure 2. Data related fusion aspects according to Khaleghi *et al.* (Khaleghi *et al.*, 2013).

(Kviesis *et al.*, 2015; Henry *et al.*, 2019) that gather data in order to provide decision support, data produced can be multimodal – qualitatively similar (homogenous) or different (heterogeneous), such as auditory, visual, tactile measurements, textual or a mixture data. The heterogeneous data can be divided (Liu *et al.*, 2020) into spatial data, temporal data, static data, dynamic data and attribute data. These representations can also be used in combination with temporal data, i.e. spatial-temporal data (Atluri, Karpatne, & Kumar, 2018), which contain both time dimension and space dimension. In PB, spatial-temporal data are used for weather forecast.

In case of wireless sensor networks (Meikle & Holst, 2015; Ampatzidis *et al.*, 2016; Kviesis, Komasilovs, & Komasilova, 2020) sensor nodes are likely to be exposed to the same external noise that can bias measurements of these sensors; therefore, it is important to establish correct data correlation. This is especially important for large industrial grade apiaries. In addition, acquisition of data from sensors may introduce a problem called data alignment of registration, which occurs when data from each sensor's local frame are transformed into a common frame prior to fusion process (Khaleghi *et al.*, 2013).

Another challenging problem is data association, which occurs in scenarios of multi-target tracking, typically divided into two forms (Sheng *et al.*, 2018): measurement-to-track and track-to-track association. The former refers to the challenge of identifying the source of data, while the latter refers to the problem of distinguishing between tracks.

Either local sensor node or central computer processes the data, thus introducing centralised and decentralised sensor system architecture. Decentralised architecture is preferable in case of wireless sensor networks (Murakami *et al.*, 2007; Kviesis & Zacepins, 2015; Debauche *et al.*, 2018), as it allows each sensor to process data locally, i.e., eliminating outliers and other imperfections. Appliance of decentralised architecture in PB allows each sensor node to be responsible for particular physical variable's observation. As there are typically (Ferrari *et al.*, 2008; Chang & Bai, 2018; Debauche *et al.*, 2018) multiple modules per beehive, each for particular variable, decentralised architecture, where each module can process raw data itself, reduces the overall load of main system.

Depending on sensor system architecture, raw input data can be compressed into lower dimensional data, introducing some level of compression loss (Zhu *et al.*, 2005).

Multi sensor data collection also introduces such challenge as operational timing. Data from sensors may be collected in different timeframes, thus requiring for data fusion algorithm to implement

varying time scales. The main issue with different timeframes, especially in real-time applications, is the out-of-sequence arrival of data (Besada-Portas *et al.*, 2011). Operational timing can also introduce another challenge – processing the static and dynamic data. The former refers to data that are time-invariant, while latter – to data varying with time. In some cases the latter may require incorporating history of measurements to perform data fusion correctly (Brooks *et al.*, 2009) in order to acquire knowledge about data freshness, i.e. how quickly data sources capture changes and update accordingly (Khaleghi *et al.*, 2013).

Data of precision beekeeping

The type of raw data in PB is determined by the source that produces these data, whereas there are currently multiple variations of data sources in the field of PB.

Primarily the distinction between data levels must be defined. There are three distinct levels defined (Human *et al.*, 2013; Zacepins & Stalidzans, 2013): apiary, colony and individual bee-related levels.

Apiary level data includes meteorological and video observation data. Main meteorological parameters are wind and precipitations. Apiary management software tend to use (Braga *et al.*, 2020) third party weather stations to acquire these parameters. Spatial observations allow identifying the type of fields and crops (Atluri, Karpatne, & Kumar, 2018; Calatayud-Vernich *et al.*, 2019) that are usable for bee foraging. The sources of apiary level data are broad angle video cameras, local apiary weather stations, public weather stations and satellite imagery services.

Colony level data includes temperature, humidity, weight, sound, vibration and video data. Temperature, weight and humidity are the most popular parameters (Stalidzans & Berzonis, 2013; Meikle & Holst, 2015), whereas swarming and colony death are the most popular (Ferrari *et al.*, 2008; Kridi, De Carvalho, & Gomes, 2014) monitor objectives. Researchers use these parameters to determine such beehive states as broodlessness, intensive brood rearing, swarming, pre-swarming and after swarming, overheating, as well as colony death. Sound and video data are also used to determine air and noise pollution. Researchers use sound and vibrations (Bencsik *et al.*, 2015) to determine such beehive states as queenlessness, broodlessness, swarming (including prior and after swarming periods), beehive overpopulation and colony death. The sources of colony level data are temperature sensors, humidity sensors, weight sensors, noise and sound receivers, mono and multispectral video cameras.

The individual bee-related monitoring addresses such objectives as bee counting, i.e., bees going in/out of hive (Souza Cunha *et al.*, 2020), amount of infested

bees (Bjerge *et al.*, 2019), and bee activity (Ngo *et al.*, 2019). The sources of individual bee-related data are mainly mono and multispectral video cameras.

Depending on the data level and parameters, researchers and apiary management system developers define a system architecture that can realise these principles (Murakami *et al.*, 2007; Kvisis *et al.*, 2015; Kridi, de Carvalho, & Gomes, 2016; Zacepins *et al.*, 2017a; Zacepins *et al.*, 2017b, Debauche *et al.*, 2018): (1) use as few sensors as possible to minimize diminishing returns, (2) optimize the efficiency of sensor workload by using on-off cycles, (3) use web/cloud based storage, (4) sufficient scalability for future upgrades.

Data fusion approach applications in precision beekeeping

Based on conducted research, I can conclude that applications of data fusion approach in PB define the requirements for data sets with applications targeting broad objectives, such as spatial positioning of the beehive colony and short-term prediction of weather conditions.

Spatial positioning refers to selection of most efficient position of individual beehive colonies in the framework of available apiary borders. The efficiency is determined by the amount of honey produced by bees during a particular period. The following data sets, respectively, raw data layers for data fusion, must be included into processing: the location, size and borders of an apiary, the types and sizes of nearby fields and available vegetation (including seasonal blooming), the status of pesticide or other harmful chemical use on these fields, nearby and dividing roads, Earth's terrain and its landforms. The amount of bees leaving and entering beehive during a particular period and the changes in the weight of beehive during this period must be taken into account as well. The objective of short-term prediction of weather conditions refers to predicting wind and precipitations in the closest two hours in order to manage bee lifecycle, i.e. automatically closing the beehive gates or changing inside temperature. Hennessy *et al.* proved (Hennessy

et al., 2020) that wind has direct and indirect effects on foraging of worker bees (*Apis mellifera*). The former indicates that foraging rate lowers with increase of wind speed, while latter introduces hesitation of taking off from flowers after nectar gathering. Wind can also transfer harmful substances from nearby fields to foraging areas (Gamboa *et al.*, 2020). Precipitations affect foraging rate and bee lifespan as heavy rain can break bee's wings. He *et al.* proved (He *et al.*, 2016) that bees work harder before heavy precipitations. The following data sets must be included into processing: air humidity in a particular period, beehive inside/outside temperature in a particular period, weather forecast, wind speed, wind direction.

Conclusions

Data fusion is not a novel research topic; however, there are still ongoing debates about proper data fusion terminology, methodology and classification. It can be concluded, that data fusion is and will be a hot topic between researchers in the coming years as it correlates well with developing machine learning topic. It can also be concluded, that data fusion approach applications in the framework of precision beekeeping is a novel idea, and is yet to be researched.

The choice of data fusion method depends on the raw input data sets, as input raw data plays the major role in the data fusion process by determining the correctness and quality of information. The sensors or input data do not determine the need of data fusion for beekeeping related data; rather, it is a global objective, which requires the use of multiple multimodal input data provided by a multi sensor system. Practical applications do not introduce objectively serious technical data fusion challenges as do data type and attributes of input data.

Acknowledgements

Scientific research, publication and presentation are supported by HIVEOPOLIS project that is funded by the Horizon 2020 FET Programme of the European Union under grant agreement No. 824069.

References

- Allen, G.D. (2004). Hierarchy of Knowledge – from Data to Wisdom. *International Journal of Current Research in Multidisciplinary (IJCRM)*, 2(1), 15–23.
- Ampatzidis, Y., Tan, L., Haley, R., & Whiting, M.D. (2016). Cloud-based harvest management information system for hand-harvested specialty crops. *Computers and Electronics in Agriculture*, 122, 161–167. DOI: 10.1016/j.compag.2016.01.032.
- Atluri, G., Karpatne, A., & Kumar, V. (2018). Spatio-temporal data mining: A survey of problems and methods. *ACM Computing Surveys*, 51(4), 1–37. DOI: 10.1145/3161602.
- Beddar-Wiesing, S., & Bieshaar, M. (2020). Multi-Sensor Data and Knowledge Fusion – A Proposal for a Terminology Definition. *ArXiv*. Retrieved January 27, 2020, from <http://arxiv.org/abs/2001.04171>.
- Bellinger, G., Castro, D., & Mills, A. (2003). *Data, Information, Knowledge, and Wisdom*. 5–7. Retrieved January 27, 2020, from <http://outsights.com/systems/dikw/dikw.htm>.

- Bencsik, M., Le Conte, Y., Reyes, M., Pioz, M., Whittaker, D., Crauser, D., ... Newton, M.I. (2015). Honeybee colony vibrational measurements to highlight the brood cycle. *PLoS ONE* 10(11): No. 1371. DOI: 10.1371/journal.pone.0141926.
- Besada-Portas, E., Lopez-Orozco, J.A., Besada, J., & De La Cruz, J.M. (2011). Multisensor fusion for linear control systems with asynchronous, Out-Of-Sequence and erroneous data. *Automatica*, 47(7), 1399–1408. DOI: 10.1016/j.automatica.2011.02.030.
- Bjerger, K., Frigaard, C.E., Høgh Mikkelsen, P., Holm Nielsen, T., & Misbih, M. (2019). A computer vision system to monitor the infestation level of *Varroa destructor* in a honeybee colony. *Computers and Electronics in Agriculture*, 164. DOI: 10.1016/j.compag.2019.104898.
- Blasch, E.P., & Plano, S. (2002). JDL level 5 fusion model: user refinement issues and applications in group tracking. In *AeroSense 2002*, 2002, Orlando, FL, United States. 31 July 2002. Proc. SPIE 4729, *Signal Processing, Sensor Fusion, and Target Recognition XI*, 4729, 270–279. DOI: 10.1117/12.477612.
- Brooks, A., Makarenko, A., Kaupp, T., Durrant-Whyte, H., & Dellaert, F. (2009). Decentralised Data Fusion with Dynamic Topologies – A Graphical Model Approach. *IFAC Proceedings Vol. 42(20)*, 222–227. DOI: 10.3182/20090924-3-it-4005.00038.
- Calatayud-Vernich, P., Calatayud, F., Simó, E., Pascual Aguilar, J.A., & Picó, Y. (2019). A two-year monitoring of pesticide hazard in-hive: High honey bee mortality rates during insecticide poisoning episodes in apiaries located near agricultural settings. *Chemosphere*, 232, 471–480. DOI: 10.1016/j.chemosphere.2019.05.170.
- Castanedo, F. (2013). A review of data fusion techniques. *The Scientific World Journal*, 2013, No. 704504, p. 19. DOI: 10.1155/2013/704504.
- Chang, N., & Bai, K. (2018). Concepts and Basics of Image and Data Fusion. *Multisensor data fusion and machine learning for environmental remote sensing* (pp. 168–170). Taylor and Francis Group. Boca Raton, Florida. DOI: 10.1201/b20703.
- Gamboa, L.G., Diaz, K.S., Ruepert, C., & van Wendel de Joode, B. (2020). Passive monitoring techniques to evaluate environmental pesticide exposure: Results from the Infant’s Environmental Health study (ISA). *Environmental Research*, 184(May 2020), No. 109243. DOI: 10.1016/j.envres.2020.109243.
- Debauche, O., Moulat, M.El., Mahmoudi, S., Boukraa, S., Manneback, P., & Lebeau, F. (2018). Web Monitoring of Bee Health for Researchers and Beekeepers Based on the Internet of Things. *Procedia Computer Science*, 130, 991–998. DOI: 10.1016/j.procs.2018.04.103.
- Ferrari, S., Silva, M., Guarino, M., & Berckmans, D. (2008). Monitoring of swarming sounds in bee hives for early detection of the swarming period. *Computers and Electronics in Agriculture*, 64(1), 72–77. DOI: 10.1016/j.compag.2008.05.010.
- Hall, D.L., & Llinas, J. (1997). An introduction to multisensor data fusion. *Proceedings of the IEEE*, 85(1), 6–23. DOI: 10.1109/5.554205.
- He, X.J., Tian, L.Q., Wu, X.B., & Zeng, Z.J. (2016). RFID monitoring indicates honeybees work harder before a rainy day. *Insect Science*, Vol. 23, 157–159. DOI: 10.1111/1744-7917.12298.
- Hennessy, G., Harris, C., Eaton, C., Wright, P., Jackson, E., Goulson, D., & Ratnieks, F.F.L.W. (2020). Gone with the wind: effects of wind on honey bee visit rate and foraging behaviour. *Animal Behaviour*, 161, 23–31. DOI: 10.1016/j.anbehav.2019.12.018.
- Henry, E., Adamchuk, V., Stanhope, T., Buddle, C., & Rindlaub, N. (2019). Precision apiculture: Development of a wireless sensor network for honeybee hives. *Computers and Electronics in Agriculture*, 156(June 2018), 138–144. DOI: 10.1016/j.compag.2018.11.001.
- Human, H., Brodschneider, R., Dietemann, V., Dively, G., Ellis, J. D., Forsgren, E., ... Zheng, H.Q. (2013). Miscellaneous standard methods for *Apis mellifera* research. *Journal of Apicultural Research*, 52(4), DOI: 10.3896/IBRA.1.52.4.10.
- Khaleghi, B., Khamis, A., Karray, F.O., & Razavi, S.N. (2013). Multisensor data fusion: A review of the state-of-the-art. *Information Fusion*, 14(1), 28–44. DOI: 10.1016/j.inffus.2011.08.001.
- Kridi, D.S., de Carvalho, C.G.N., & Gomes, D.G. (2016). Application of wireless sensor networks for beehive monitoring and in-hive thermal patterns detection. *Computers and Electronics in Agriculture*, 127, 221–235. DOI: 10.1016/j.compag.2016.05.013.
- Kridi, D.S., de Carvalho, C.G.N., & Gomes, D.G. (2014). A predictive algorithm for mitigate swarming bees through proactive monitoring via wireless sensor networks. In *Proceedings of the 11th ACM Symposium on Performance Evaluation of Wireless Ad Hoc, Sensor, and Ubiquitous Networks*. Association for Computing Machinery, New York, USA, 21–26 September 2014 (pp. 41–47). DOI: 10.1145/2653481.2653482.

- Kumar, M., Garg, D.P., & Zachery, R.A. (2006). A generalized approach for inconsistency detection in data fusion from multiple sensors. In Proceedings of the American Control Conference, 14-16 June 2006 (pp. 2078–2083). DOI: 10.1109/acc.2006.1656526.
- Kviesis, A., Komasilovs, V., & Komasilova, O. (2020). Application of fuzzy logic for honey bee colony state detection based on temperature data. *Biosystems Engineering*, 193, 90–100. DOI: 10.1016/j.biosystemseng.2020.02.010.
- Kviesis, A., & Zacepins, A. (2015). System architectures for real-time bee colony temperature monitoring. *Procedia Computer Science*, 43(C), 86–94. DOI: 10.1016/j.procs.2014.12.012.
- Kviesis, A., Zacepins, A., Durgun, M., & Tekin, S. (2015). Application of wireless sensor networks in precision apiculture. In Proceedings of 14th International Scientific Conference Engineering for Rural Development, 20–22 May 2014 (pp. 440–445). Jelgava, Latvia.
- Liu, J., Li, T., Xie, P., Du, S., Teng, F., & Yang, X. (2020). Urban big data fusion based on deep learning: An overview. *Information Fusion*, 53(June 2019), 123–133. DOI: 10.1016/j.inffus.2019.06.016.
- Llinas, J., Bowman, C., Rogova, G., Steinberg, A., Waltz, E., & White, F. (2004). Revisiting the JDL data fusion model II. In Proceedings of the Seventh International Conference on Information Fusion, 28 June 1 July 2004 (pp. 1218–1230). Stockholm, Sweden: Computer Science.
- Luo, R.C., Yih, C.C., & Su, K.L. (2002). Multisensor fusion and integration: Approaches, applications, and future research directions. *IEEE Sensors Journal*, 2(2), 107–119. DOI: 10.1109/JSEN.2002.1000251.
- Meikle, W.G., & Holst, N. (2015). Application of continuous monitoring of honey bee colonies. *Apidologie*, 46(1), 10–22. DOI: 10.1007/s13592-014-0298-x.
- Murakami, E., Saraiva, A.M., Ribeiro, L.C.M., Cugnasca, C.E., Hirakawa, A.R., & Correa, P.L.P. (2007). An infrastructure for the development of distributed service-oriented information systems for precision agriculture. *Computers and Electronics in Agriculture*, 58(1), 37–48. DOI: 10.1016/j.compag.2006.12.010.
- Ngo, T.N., Wu, K.C., Yang, E.C., & Lin, T.T. (2019). A real-time imaging system for multiple honey bee tracking and activity monitoring. *Computers and Electronics in Agriculture*, 163(1), No. 104841. DOI: 10.1016/j.compag.2019.05.050.
- Peng, W., Deng, H., & Chen, A. (2020). Using Hellinger and Bures metrics to construct two-dimensional quantum metric space for weather data fusion. *Information Fusion*, 55(September 2019), 199–206. DOI: 10.1016/j.inffus.2019.09.004.
- Braga, A.R., Gomes, D.G., Rogers, R., Hassler, E., Freitas, B.M., & Cazier, J.A. (2020). A method for mining combined data from in-hive sensors, weather and apiary inspections to forecast the health status of honey bee colonies. *Computers and Electronics in Agriculture*, 169(September 2019), No. 105161. DOI: 10.1016/j.compag.2019.105161.
- Sheng, X., Chen, Y., Guo, L., Yin, J., & Han, X. (2018). Multitarget tracking algorithm using multiple GMPHD filter data fusion for sonar networks. *Sensors (Switzerland)*, 18(10), No. 3193. DOI: 10.3390/s18103193.
- Solaiman, B. (1999). Multisensor data fusion using fuzzy concepts: application to land-cover classification using ers-l/jers-1 sar composites. *IEEE Transactions on Geoscience and Remote Sensing*, 37(3 I), 1316–1326. DOI: 10.1109/36.763295.
- Souza Cunha, A.E., Rose, J., Prior, J., Aumann, H.M., Emanetoglu, N.W., & Drummond, F.A. (2020). A novel non-invasive radar to monitor honey bee colony health. *Computers and Electronics in Agriculture*, 170, No. 105241. DOI: 10.1016/j.compag.2020.105241.
- Stalidzans, E., & Berzonis, A. (2013). Temperature changes above the upper hive body reveal the annual development periods of honey bee colonies. *Computers and Electronics in Agriculture*, 90, 1–6. DOI: 10.1016/j.compag.2012.10.003.
- Targowski, A. (2005). From Data to Wisdom. *Dialogue and Universalism*, 15(5), 55–71. DOI: 10.5840/du2005155/629.
- White, F.E. (1991). Data Fusion Lexicon. *The Data Fusion Subpanel of the Joint Directors of Laboratories, Technical Panel for C3*, USA: U.S. Department of Defense, p. 15. Retrieved March 10, 2020, from <https://apps.dtic.mil/docs/citations/ADA529661>.
- Zacepins, A., Stalidzans, E., & Meitalovs, J. (2012). Application of Information Technologies in Precision Apiculture. In Proceedings of the 13th International Conference on Precision Agriculture (ICPA 2012), 31 July 3 August 2012, Indianapolis, Indiana USA.
- Zacepins, A., Pecka, A., Osadcuks, V., Kviesis, A., & Engel, S. (2017a). Solution for automated bee colony weight monitoring. *Agronomy Research*, 15(2), 585–593.
- Zacepins, A., Brusbardis, V., Meitalovs, J., & Stalidzans, E. (2015). Challenges in the development of Precision Beekeeping. *Biosystems Engineering*, 130, 60–71. DOI: 10.1016/j.biosystemseng.2014.12.001.

Zacepins, A., Kvišis, A., Pecka, A., & Osadcuks, V. (2017b). Development of Internet of Things concept for Precision Beekeeping. In Proceedings of 18th International Carpathian Control Conference, 28–31 May, 2017 (p. 23–27). DOI: 10.1109/CarpathianCC.2017.7970365.

Zacepins, A., & Stalidzans, E. (2013). Information processing for remote recognition of the state of bee colonies and apiaries in precision beekeeping (apiculture). *Biosystems and Information Technology*, 2(1), 6–10. DOI: 10.11592/bit.130502.

Zhang, Y., Meratnia, N., & Havinga, P. (2010). Outlier detection techniques for wireless sensor networks: A survey. *IEEE Communications Surveys and Tutorials*, 12(2), 159–170. DOI: 10.1109/SURV.2010.021510.00088.

Zheng, Y. (2015). Methodologies for Cross-Domain Data Fusion: An Overview. *IEEE Transactions on Big Data*, 1(1), 16–34. DOI: 10.1109/tbdata.2015.2465959.

Zhu, Y., Song, E., Zhou, J., & You, Z. (2005). Optimal dimensionality reduction of sensor data in multisensor estimation fusion. *IEEE Transactions on Signal Processing*, 53(5), 1631–1639. DOI: 10.1109/TSP.2005.845429.

FINANCIAL SECTOR EVOLUTION AND COMPETENCIES DEVELOPMENT IN THE CONTEXT OF INFORMATION AND COMMUNICATION TECHNOLOGIES

*Ilja Arefjevs¹, Aivars Spilbergs¹, Andris Natrins¹, Atis Verdenhofs², Inese Mavlutova¹, Tatjana Volkova¹

¹BA School of Business and Finance, Latvia

²Riga Technical University, Latvia

*Corresponding author's email: ilja.arefjevs@inbox.lv

Abstract

The development of information and communication technologies (ICT) has a significant impact on the business model of companies operating in the financial sector. Digital transformation leads to changing existing business model rapidly, as well as necessity of developing new processes specifically related to the use of ICT in business processes, development of new products and updating existing ones. At present, changes in the demand for ICT related processes in financial sector are observed both through the development of different technologies and their applications core or ancillary processes (e.g. innovations in payment systems including crypto currencies, blockchain-assisted smart contract, credit markets and insurance including peer-to-peer lending). Based on the opportunities offered by ICT, new business models need to be developed in the financial sector to transform these capabilities into new products and services that respond to changing customer demand.

The aim of research to investigate the changes taking place in financial sector in the light of developments in ICT for acquisition of necessary competencies.

Research methodology includes systematic review of scientific literature, analysis of selected financial sector statistics, semi-structured industry expert interviews and statistics analysis.

The empirical study is limited to the financial sector of Latvia. Although due to the global nature of the financial sector the research findings could be applied internationally.

Key words: financial sector, fintech companies, ICT, digital competencies, soft skills.

Introduction

Financial intermediation has changed dramatically over the past 30 years, largely due to technological change arising from advances in telecommunications, information technology, and financial practice (Frame *et al.*, 2018). On the other hand, according to Gregory *et al.*, (2018) banks face increasingly stringent regulatory and complex requirements in order to limit business risks. To comply with these requirements, robust governance and complex ICT infrastructures must be ensured (Gregory *et al.*, 2018). This compliance agenda has never been so topical for Latvia as in recent years. Latvia positioned itself as a potential financial centre for the region, supported by the government order No.126 'On the Financial Sector Development Plan 2017–2019'; however, the amendments of 13 February, 2019 changed this objective to 'develop a stable, secure and internationally competitive financial sector with access to innovative financial services that ensure sustainable growth of the Latvian economy' (On the Financial Sector Development Plan 2017–2019, 2019). Researchers Kotarba (2017), Supe *et al.*, (2019) and others emphasize that digital transformation has influenced changes in the financial sector. Currently, commercial banks are competing with banks for new technology companies, whose products overlap with those offered by banks. With the rapid development of technology, they have also entered the financial services industry, making our lives more comfortable. Arner *et al.*, (2015) consider that 'FinTech' refers to technology enabled financial solutions. Although financial technology companies

may not be able to fully utilize banking services in their technology solutions, they still create products where the user is not tied to a particular bank as a customer.

Anagnostopoulos (2017) believes that fintech companies have reached the main channels of commercial banks through technology and innovation in the financial sector. Drasch, Schweizer and Urbach (2018) agree with Anagnostopoulos (that banks are struggling with innovation opportunities, while fintech companies offer technology-enabled capabilities, thus disrupting the value propositions of classical banks). Thakor (2019) suggests that 'Fintech is the use of technology to provide new and improved financial services. Part of the motivation for the emergence of Fintech is that, while information technology has made everything cheaper and more functional, the unit cost of financial intermediation has apparently not changed much in over a century'.

According to Natrins *et al.*, (2019) digital transformation of financial sector is among the most actively researched topics in academic publications in last ten years. According to systematic literature review performed by Verdenhofs, A. & Tamboveceva, T. in 2018 for successful usage of big data solutions in financial institutions, there should be successful merge of three parties within organization – ICT, analytics and management.

Banks have become both providers of technology as well as users, integrating advanced tools to improve the financial services offered to its clients, both in the corporate and retail business (European banking

federation, 2018). Technological innovations in the areas of big data, data analysis and mobile devices allow fintech start-ups to support traditional banks with personalized services (Lee & Shin, 2018). For commercial banks, there is much to learn from how fintech companies are designing the customer proposition and how they are harnessing technology to deliver compelling services (Gulamhuseinwala *et al.*, 2015). The authors agree with Navaretti *et al.*, that in the future the business model of fintech companies, therefore, is highly likely to gradually converge towards that of banks (Navaretti *et al.*, 2017) as there is potential based on experience to ensure brand recognition, expand customer basis through a wide range of product offerings, developing robust digital infrastructure, develop advanced underwriting capabilities, develop risk management experience, extend access to capital and to get license to provide regulated financial services. Giebe concludes that in the era of digitalization one way to manage the organization effectively is to introduce a Chief Digital Officer (CDO) with the central task to execute and implement the change processes (Giebe, 2019).

Materials and Methods

Authors of the research conducted a systematic review of scientific literature, analysis of selected financial sector statistics as well as performed semi-structured industry expert interviews. According to Kelly *et al.*, 2017, the financial institutions have brand/name recognition, large customer base, a wide range of product offerings, comprehensive customer data, robust infrastructure, advanced underwriting

capabilities, risk management experience, access to capital, licensed to provide regulated financial services (Kelly *et al.*, 2017).

Fintech company prospects are highly appreciated, and the press presents these companies as ‘disruptive’, ‘revolutionary’ that will ‘destroy’ traditional barriers and financial institutions (World Economic Forum, 2017). According to Mavlutova, I. and Volkova, T. (2019) traditional financial service providers like commercial banks and providers of digital innovations like fintech companies can be described not as competitors but as partners in several aspects. Therefore, in the course of the research hypotheses are stated as follows:

H₁: average growth of operating income of commercial banks outpaced average growth of number of banking branches and customer service units (to be accepted or rejected based on statistics tests).

H₂: growth of both a transaction numbers and volume at terminals with payment cards outpaced the growth of Gross Domestic Product (to be accepted or rejected based on statistics tests).

H₃: soft skills of employees are at least as important as digital skills in the financial sector development in the context of evolution of information and communication technologies (to be accepted or rejected based on a critical assessment of expert interview findings).

The underlying logic of hypotheses was first to test whether there has been an effective shift towards digital channels in the financial sector of Latvia and what kind of implications, if any, on certain competences (i.e. digital skills vs. soft skills of employees) it brings.

Table 1

Interviewed experts for the purpose of this research

Expert #	Organisation	Position	Industry
1	AS Swedbank	Head of Digital Innovation and Strategy	Banking
2	AS SEB banka	Head of Front Channels, Baltics	Banking
3	AS SEB banka	Innovation Manager	Banking
4	Citadele Bank AS	Head of E-Business Division	Banking
5	SEB Global Services Riga	Deputy Head	Shared Services
6	IPAS Indexo	Chairperson of the Management Board	Asset Management
7	AAS Balta	Member of the Management Board, Technical Director	Insurance
8	AS mogo	Chief Executive Officer	Car leasing (Financial Technology)
9	SIA UniCredit Leasing Latvia	Branch Manager	Leasing (conventional)
10	Robocash Group	Chief Risk Officer	Consumer lending, marketplace funding
11	Bigbank AS Latvia Branch	Member of the Management Board	Consumer and business lending
12	JSC 4finance	Chief Risk Officer	Consumer lending

Key objectives of the empirical research are set to be:

1. Study importance of the financial sector of Latvia in the medium term perspective.
2. Study the development of a number of banking branches, operating income as well as a total number and total volume of point-of-sale terminal transactions as well as perform statistics tests.
3. Study importance of digital skills and soft skills of employees working for the financial sector.
4. Study alternatives to acquire and improve certain sets of digital skills of employees demanded by the financial sector.

For the purpose of structured expert interviews on chosen topics, expert candidates have been selected according to the following three criteria – affiliation to an industry of the financial sector, senior or executive management position and industry track record of at least 10 years.

Experts to be interviewed were chosen from the most significant industries so that the combined opinion of all experts would represent the entire financial sector of Latvia. The banking industry prevails since it is the most significant one within the financial sector. Since the banking sector of Latvia and Baltics is largely dominated by Nordic companies (Arefjevs, 2017), four experts from largest financial groups were included in the list. Consumer lending is also widely presented since this is a fast growing industry, which is expanding abroad too. Expert interviews were conducted in the time period from December 2019 till February 2020.

The average interview lasted one hour and was conducted either in person or over phone. The interview language was either English or Latvian. After the interview a condensed summary of expert answers was drafted in English and delivered to

the interviewed expert for proofreading. Therefore, expert interview findings presented in the research in a concentrated manner in English have been proofread by experts.

Results and Discussion

The financial sector of Latvia changed its operating model substantially after a major crisis in 2008–2009. On the one hand, cutting down banking branch networks was triggered by a need of implementing strict cost saving measures. On the other hand, rapidly developing digital technologies and high adoption rates among banking customers clearly facilitates the process of a shift from face-to-face channels to a remote service mode. In particular, the Figure 1 illustrates an obvious downtrend of number of banking branches and customer service units (B&CSU) from 2010 to 2018. The total operating income of banks, largely reflecting commissions and fees collected in branches in the past, does not show signs of sustainable decline.

Further, the authors checked the difference between average trends in numbers of banking branches, customer service units and operating income of commercial banks during 2010–2018. The following hypotheses were tested: operating income of commercial banks during 2010–2018 is growing faster than numbers of banking branches, customer service units of commercial banks. For these statistics tests the hypotheses were designed as follows:

$$H_{1(0)}: \mu_{OI} - \mu_{BCSU} \leq 0$$

$$H_{1(A)}: \mu_{OI} - \mu_{BCSU} > 0$$

where: μ_{OI} – average growth of operating income of commercial banks during 2011–2018, % to 2010,
 μ_{BCSU} – average growth of number of banking branches and customer service units of commercial banks during 2011–2018, % to 2010.

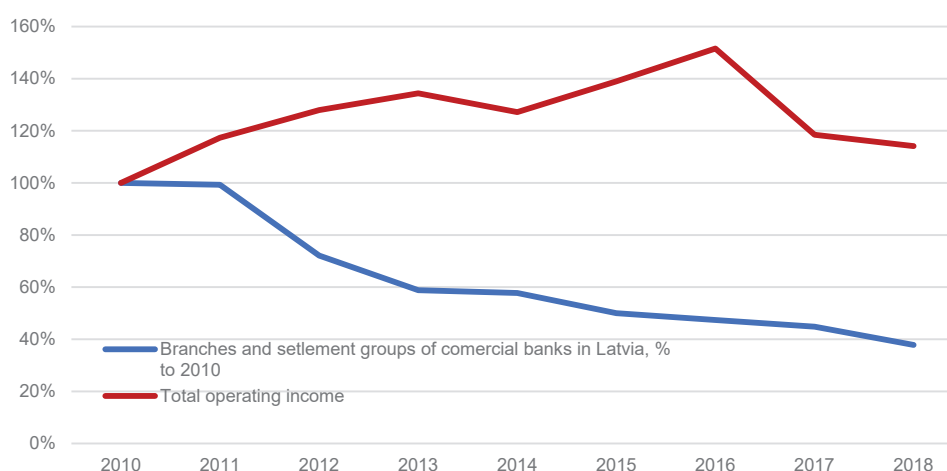


Figure 1. Branches, CSU and operating income of commercial bank trends, % to 2010.

Source: compiled by authors based on FCMC data.

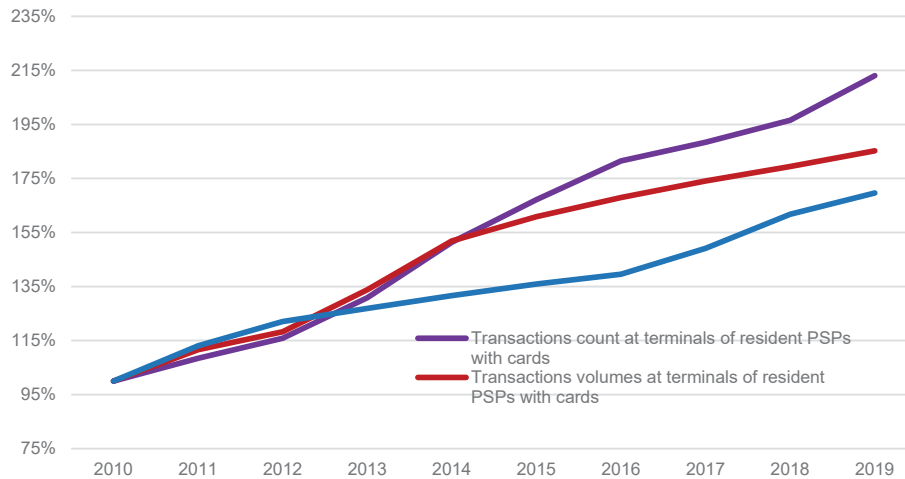


Figure 3. Transaction numbers and volumes at terminals with cards and GDP trends, % to 2010.

Source: compiled by authors based on BoL and CSB data.

Based on FCMC data (FCMC, 2020) and using the Students's *t*-test with a critical value = 0.05, the authors computed Student's *t*-statistic (7.8315), compared it with critical value (1.8946) and rejected null hypothesis. It can be concluded from this hypothesis testing that there is strong evidence that operating income of commercial banks is growing faster than numbers of banking branches and customer service units. This conclusion is supported with very low *p*-values ($p = 0.00005$).

Additionally, both the total number of transactions as well as the total volume of transactions made in the point-of-sale terminals demonstrated stable growth trends, as shown in the Figure 3. It is noteworthy that the total number of transactions grew twice as fast as the total transaction volume clearly pointing to the fact of a declining value of an average transaction volume, which is generally a very typical pattern when some service is being widely adopted.

Further, the authors checked the difference between average trends in numbers and volumes of

transactions at terminals of resident PSPs with cards and GDP growth during 2010–2019. The following hypotheses were tested: both, numbers and volumes of transactions at terminals of resident PSPs with cards during 2010–2019 is growing faster than GDP. For this research, the hypotheses were designed as follows:

Based on Bank of Latvia (BoL, 2020) and CSB (CSB, 2020) data and using the Students's *t*-test with a critical value $\alpha = 0.05$, the authors computed Student's *t*-statistics (3.3735 vs 3.7921), compared it with critical value (1.8595) and rejected both null hypothesis.

It can be concluded from this hypothesis testing that there is strong evidence that both, numbers and volumes of transactions at terminals of resident PSPs with cards are growing faster than GDP. This conclusion is supported with very low *p*-values ($p = 0.0049$ vs 0.0026 respectively).

Proceeding with expert interview findings, the first question was defined as *How do you see importance of*

Table 2

Null and alternative hypothesis statements for transactions numbers and volumes at terminals with cards and GDP trends

Hypothesis type	GDP vs transactions numbers	GDP vs transactions volumes
$H_{2(0)}$:	$\mu_{TN} - \mu_{GDP} \leq 0$	$\mu_{TV} - \mu_{GDP} \leq 0$
$H_{2(A)}$:	$\mu_{TN} - \mu_{GDP} > 0$	$\mu_{TV} - \mu_{GDP} > 0$

where: μ_{GDP} – average GDP growth during 2011–2019, % to 2010;

μ_{TN} – average growth of transaction numbers at terminals of resident PSPs with cards during 2011–2019, % to 2010;

μ_{TV} – average growth of transaction volumes at terminals of resident PSPs with cards during 2011–2019, % to 2010.

the financial sector for the economy in Latvia now and in the nearest future?

The condensed summary of expert answers suggests that the financial sector is very significant for the economy and can be considered to be its backbone. There are reasons to believe that the financial sector is becoming increasingly critical for the economy due to rapid digitalisation (i.e. role of cash is decreasing, transactions are performed mostly digitally via intermediation of the financial sector). In general, the financial environment in Latvia can be considered to be very stable (i.e. taking the financial sector and the monetary system in a broad way). In future, further growth is expected. Faster transactions will facilitate consumption and thus economy in general. A number of transactions is poised to jump substantially. Services will become highly available due to technologies. User experience will become increasingly important.

Latvia-based financial technology companies are successfully expanding their operations outside Latvia, thus to some extent compensating a negative impact caused by shrinking the so-called non-resident sector.

Anti money laundering matters are clearly in the focus and potentially might be exaggerated at the moment both in Latvia and other Baltic countries (i.e. Estonia, Lithuania). Thus, negative consequences are expected to persist in the nearest future. On the other hand, importance of the financial sector increased due to new functions in relation to sanction screening and transaction monitoring.

The second question was forward looking and phrased in the following way: *How would you briefly describe future of the financial sector in five years from now and longer?*

a. Products and services:

Experts responded that traditional products and services are generally expected to stay. However, more automation (and less human involvement) as well as other technology advances are clearly expected - more precise customer profiling, clear shift from physical branched to online operations, real time analysis and transaction execution, smooth and simple processes. Biometrical parameters will be in use increasingly more often. A shift from using mobile phones to chats and bots is already taking place. Employees released from simple jobs will solve more complicated customer cases.

Products and services will become less visible. There will be increasingly less need for customers to go after a product or service. Rather products and services will reach customers when they need it. Different customer behaviour is expected depending on a customer generation though. Younger generations will be more open to technology advances like certain virtual services (e.g., robo-advisory, self-services).

Customer insights will add more value to offering right products to right customers. Other researchers (e.g., Vives, 2018) also believe that new digital technologies automate potentially may provide new and more cost-effective products in parts of the financial sector, ranging from lending to asset management, portfolio advice and the payment system.

More harmonisation across regions expected. Further product and process simplification is expected to take place. Thus, financial products and services will be easier to understand and to use by the general public. There will be some exceptions though. For instance, business-to-business products will still be tailor-made to a large extent. On the other hand, underserved segments like small and medium enterprises will get more attention via simplified and accessible offering, thus being able to develop faster than the financial sector in general.

b. Local vs international vs global

Experts believe that financial services provision borders are expected to disappear. Already now financial products are being developed globally (e.g., wide insurance coverage etc.). Globalisation of certain services already takes place, especially for digital providers, to whom a customer residence is not important from an operational point of view. Thus, a geographical expansion is possible in case of very focused attractive products and services (eg. Revolut, N26). Thus, a potential strategy for small and agile market players is clearly present. More cross-border business, more disruptive approaches will emerge. Global technology providers have huge chances to win the race. Eventually the race between big technology companies and major central banks may arise. Legal and regulatory constraints are important though, and they are expected to stay for a longer term than five years.

Combined offering is already available (e.g., when booking a car, insurance and other services offered at the same time). Demand for local products and services can emerge due to a patriotic perspective. Emotional affirmation is still considered to be important. Therefore, there is space for localised solutions. In some cases a scale is important, in some case a local 'touch' will be appreciated. Cost efficient solutions for specific markets are possible too. Digital product offering was names as a precondition for expansion. All in all, either a scale or a uniqueness advantage can be a precondition to succeed.

The biggest tug of war is expected between local and global. Latvia faces the risk to lag behind the developed world. One reason is a smaller language in terms of a number of people using it; another is population living outside urban areas.

Authors emphasise that according to the Digital Banking report 2019 Retail banking trends and

predictions based on the survey for the first time ever among strategic priorities for 2019 (Marous, 2017), the use of big data, artificial intelligence and advanced analytics was ranked first, outpacing improving the customer experience as the number one trend for the previous years. Consequently, financial sector managers need to provide pro-active and effective competence-based management to ensure that the proper competencies are in place for achieving the business development goals and demonstrate high business performance in both short and long term. On the other hand, according to the report 'Skills and competences in the Nordic financial sector' (2019), social and adaptability skills are generally ranked higher than hard skills such as digital skills, for example, which are one of the most required hard skills. Therefore, experts have been asked to reflect on this finding in order to test H_3 : soft skills of employees are at least as important as digital skills in the financial sector development in the context of evolution of information and communication technologies.

According to the experts interviewed within the research, soft skills are somewhat more important than specific hard skills (i.e. digital skills). However, the gap is estimated to be very small. A combination of soft and hard skills is important. It was concluded that Latvia may be lacking people with hard skills in general.

Soft skills have to be continuously developed starting from the early childhood (and furthermore within organisations via internal culture). Culture diversity is one of facilitators of soft skill development. Mentorship programmes can be considered to be an effective tool to strengthen soft skills. Hard skills development can be subject to specific educational and training programmes. Problem solving and analytical skills are becoming increasingly important hard skills in the light of big data and artificial intelligence.

Delivering user experience is pivotal in the digital era. User experience comprises a function of hard and soft skills (via empathy). This is also indirectly confirmed by Chen L., Danbolt J., Holland J., 2014, who state that the way banks learn to use their intangible and tangible assets, including the competencies of managers and professionals, to create an attractive, customer-oriented service will play an important role in this competition. General digital user skills are likely to be considered to be 'default' skills in the nearest future, setting an expectation that nearly all employees should possess those. Specific competences related to big data, machine learning and robotics have to be empowered by appropriate educational programmes (i.e. higher schools and universities). Thus, on the basis of the received expert opinion, authors accept the third hypothesis stating that soft skills of employees are at least as important as digital skills in the financial sector evolution.

The authors revisited the Nordic research (2019) again to obtain expert opinions on the statement that data analysis and related skills are most likely to be maintained in-house while programming and ICT have the highest score for outsourcing and consultants. Expert interviews suggest that for each company it is important to define core competencies and develop and maintain those in-house. Other competencies can be outsourced. A specific decision is to a large extent dependent on a business model while having critical mass is a precondition for in-house competences. In particular, data analysis, maths and big data can form a core competence, which is a critical success factor for a competitive advantage, thus kept in-house. Additionally, data visualisation skills are required.

To sum up the results and discussion section, the key findings are:

1. The financial sector is very significant or even critical to the whole economy. It is expected to keep its major role in future while borders of financial services provision will disappear due to technological advancements and competition.
2. The financial sector experienced a significant shift in customer service channels from face-to-face to remote channels.
3. Soft skills of employees are found to be at least as important as digital skills in the financial sector development in the context of evolution of information and communication technologies.
4. The answer to the question about outsourcing of certain competencies (like ICT and engineering) is directly linked to core competencies of a company. Keeping analytical and problem solving competences in-house can be considered to be a common approach in the financial sector.

Conclusions

Data, capabilities of using data, data analytics and understanding of the importance of data at the strategic level are both essential factors and catalysts for the future development of the financial sector. These factors will have a major impact on the competitiveness of both financial technology companies and banks.

The financial sector is becoming increasingly critical for the economy due to rapid digitalisation. Faster transactions will facilitate consumption and thus economy in general. A number of transactions is poised to jump substantially. Services will become highly available due to technologies. User experience is expected to become increasingly important.

Latvia-based financial technology companies are successfully expanding their operations outside Latvia compensating for a negative impact caused by shrinking the non-resident banking segment.

Current development of the financial sector poses challenges from a competence management perspective to both traditional players as well as financial technology companies. Digital competences are assessed to be important; however, soft skills like social skills and adaptability ranked somewhat higher. Digital skills as well as specific big data, machine learning and robotics related skills are suggested to be acquired mainly via educational programmes while soft skills have to be mainly acquired by people themselves throughout life starting from early childhood. General preference for in-house competences are for data analysis and problem

solving while hard ICT competences are more likely to be outsourced. A decision on what competences to be kept in-house and which should be outsourced is to be taken based on considerations about core competences of a particular company, critical mass for competence maintenance and other factors.

Acknowledgment

The research was supported by the BA School of Business and Finance Internal Grant Research Project 'The Assessment of Competence Management in the Latvian Financial Sector'.

References

- Anagnostopoulos, I. (2018). Fintech and regtech: Impact on regulators and banks. *Journal of Economics and Business*, 100, 7–25.
- Arefjevs, I. (2017). Efficiency Assessment Concept Model for Financial Alliances: Bank assurance in Baltic Pension Fund Management. *European Integration Studies*, 11, 186–198.
- Arner, D. (2015). The evolution of fintech: a new Post-Crisis paradigm? Retrieved February 10, 2020, from <http://www.juliaocoelho.com/wp-content/uploads/2019/05/SSRN-id2676553.pdf>.
- Bank of Latvia. (2020). Payment statistics. Retrieved February 10, 2020, from <https://www.bank.lv/en/statistics/stat-data/payment-systems-statistics>.
- Central Statistical Bureau of Latvia. (2020). Gross domestic product. Retrieved February 10, 2020, from <https://www.csb.gov.lv/en/statistics/statistics-by-theme/economy/gdp>.
- Chen, L., Danbolt, J., & Holland, J. (2014). Rethinking bank business models: the role of intangibles. *Accounting, Auditing & Accountability Journal*.
- Drasch, B.J., Schweizer, A., & Urbach, N. (2018). Integrating the 'Troublemakers': A taxonomy for cooperation between banks and fintechs. *Journal of Economics and Business*, 100, 26–42.
- Finance Finland, Finance Norway, FA Denmark. (2019). Skills and competences in the Nordic financial sector. Retrieved January 5, 2020, from <https://www.finansnorge.no/contentassets/b16acd7f75ed4442ae2a83f284cf84ab/fellesnordisk-kompetansekartlegging-2019/nordic-competence-and-skills-report-2019.pdf>.
- Financial and Capital Market Commission. (2020). Statistics. Retrieved February 10, 2020, from <https://www.ftkk.lv/en/statistics/>.
- Frame, W.S., Wall, L.D., & White, L.J. (2018). Technological change and financial innovation in banking: some implications for fintech.
- Giebe, C. (2019). The Chief Digital Officer—Savior for the Digitalization in German Banks? *Journal of Economic Development, Environment and People*, 8(3), 6.
- Gregory, R.W., Kaganer, E., Henfridsson, O., & Ruch, T.J. (2018). IT Consumerization and the Transformation of IT Governance. *Mis Quarterly*, 42(4), 1225–1253.
- Gulamhuseinwala, I., Bull, T., & Lewis, S. (2015). FinTech is gaining traction and young, high-income users are the early adopters. *Journal of Financial Perspectives*, 3(3), 16-23.
- Harzallah, M., Berio, G., & Vernadat, F. (2005). Analysis and modelling of individual competencies: toward better management of human resources. *IEEE Transactions on systems, man, and cybernetics-part A: systems and humans*, 36(1), 187–207.
- Kelly, S., Ferenzy, D., & McGrath, A. (2017). How financial institutions and fintechs are partnering for inclusion: Lessons from the frontlines. Center for Financial Inclusion at Accion
- Kotarba, M. (2016). New factors inducing changes in the retail banking customer relationship management (CRM) and their exploration by the FinTech industry. *Foundations of management*, 8(1), 69–78.
- Lee, I., & Shin, Y.J. (2018). Fintech: Ecosystem, business models, investment decisions, and challenges. *Business Horizons*, 61(1), 35–46.
- Marous, J. (2017). Retail Banking Trends and Predictions 2019. LLC Issue, (260).
- Mavlutova, I., & Volkova, T. (2019, October). Digital Transformation of Financial Sector and Challenges for Competencies Development. In 2019 7th International Conference on Modeling, Development and Strategic Management of Economic System (MDSMES 2019). Atlantis Press.

- Medina, R., & Medina, A. (2015). The competence loop: Competence management in knowledge-intensive, project-intensive organizations. *International Journal of Managing Projects in Business*.
- Mulder, M. (2011). The concept of competence: blessing or curse? In *Innovations for competence management. Conference proceedings* (pp. 11–24).
- Natrins, A., Supe, L., Mīkelsone, E., & Sarnovics, A. (2019). Information Technology Competency Management in the Financial Sector in Latvia. In *Proceedings of the 12th International Scientific and Practical Conference. Volume II* (Vol. 98, p. 103).
- Navaretti, G.B., Calzolari, G., Mansilla-Fernandez, J.M., & Pozzolo, A.F. (2018). Fintech and Banking. Friends or Foes? Friends or Foes.
- Supe, L., Nātriņš, A., Mīkelsone, E., & Sarnovičs, A. (2019). Information Technology Competency Management in Financial Sector: Literature Review. *Rural Development* 2019, 2, 268.
- Thakor, A.V. (2019). Fintech and banking: What do we know? *Journal of Financial Intermediation*, 100833.
- Verdenhofs, A., & Tambovceva, T. (2018, May). Big Data and Associated Skills: Systematic overview. In *Economic Science for Rural Development Conference Proceedings* (No. 49).
- Vives, X. (2019). Competition and stability in modern banking: A post-crisis perspective. *International Journal of Industrial Organization*, 64, 55–69.
- White, R.W. (1959). Motivation reconsidered: The concept of competence. *Psychological review*, 66(5), 297.
- Wieczorek-Szymańska, A. (2015). Employees' Competencies Management in Bank Sector. *Reports on Economics and Finance* 1(1), 105–113.

DEEP LEARNING SOLUTION FOR CHILDREN LONG-TERM IDENTIFICATION

*Nikolajs Bumanis¹, Gatis Vitols², Irina Arhipova², Inga Meirane²

¹Latvia University of Life Sciences and Technologies, Latvia

²WeAreDots Ltd., Latvia

*Corresponding author's email: nikolajs.bumanis@llu.lv

Abstract

Deep learning algorithms are becoming default solution for application in business processes where recognition, identification and automated learning are involved. For human identification, analysis of various features can be applied. Face feature analysis is most popular method for identification of person in various stages of life, including children and infants.

The aim of this research was to propose deep learning solution for long-term identification of children in educational institutions. Previously proposed conceptual model for long-term re-identification was enhanced. The enhancements include processing of unexpected persons' scenarios, knowledge base improvements based on results of supervised and unsupervised learning, implementation of video surveillance zones within educational institutions and object tracking results' data chaining between multiple logical processes. Object tracking results are the solution we found for long-term identification realization.

Key words: neural networks, face recognition solutions, long-term person identification.

Introduction

Identifying or re-identifying a person is an essential aspect of identifying a person's identity and location by retrieving data from multiple devices (Arhipova, Vitols, & Meirane, 2020). Typical scenario in person identification is person descriptors (face characteristics, gait, etc.) extraction and comparison with previously created gallery.

Typically CCTV cameras are used to capture a person, and recognition must be performed within certain constraints, for example, different camera parameters, light variations, people specifics (facial expression, presence of facial hair, make up, aging, etc.).

If two images are taken with a few minutes or hours apart, one can assume that the person's visual appearance, for example, clothing will be the same. Such a re-identification scenario is called short-period Re-ID. If images or videos are taken at intervals of several days or months, the person's re-identification process is a long-period Re-ID (Bedagkar-Gala & Shah, 2014).

Deep learning algorithms are widely applied to a short term and long term person identification.

The aim of this research is to propose deep learning solution for long-term identification of children in schools.

Materials and Methods

Some researchers already were addressing person identification issues in controlled and non-controlled environment. For example, the solution proposed by Rothoft et al. (Rothoft *et al.*, 2017) allows to monitor children behaviour in class. To detect if children pay attention to the designed spatial area, distribution of the focus points in two dimensions are performed. After that identification of anomalous points is identified.

From deep learning algorithms, Convolutional neural network (CNN) and its derivatives, seems to be most applied as a core component for short term and long term re-identification solutions. For example, CNN network was compared with more classical and widely applied linear discriminant analysis (LDA) and support vector machines (SVM) for recognition task of 138 male and 112 female school age children data set (Vařeka, 2020). For such a small data set, all three algorithms showed similar performance of 62–64% for a single trial. However, it is known that CNN is more effective with larger data sets (Chauhan & Singh, 2019).

Researchers also address identification of abnormal activities of humans in crowded places using deep learning. For example, researchers propose

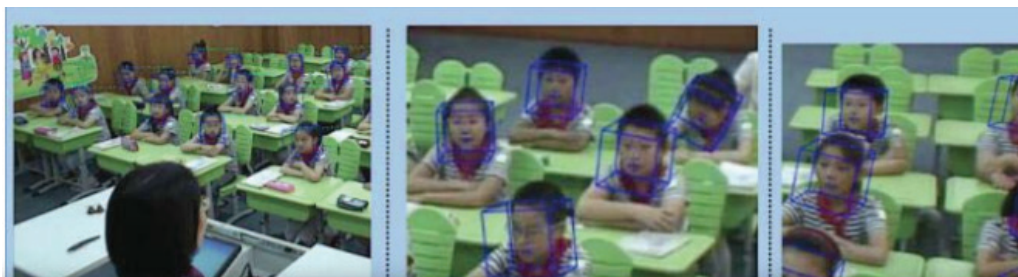


Figure 1. Focus points corresponding to inattentive students (Rothoft *et al.*, 2017).

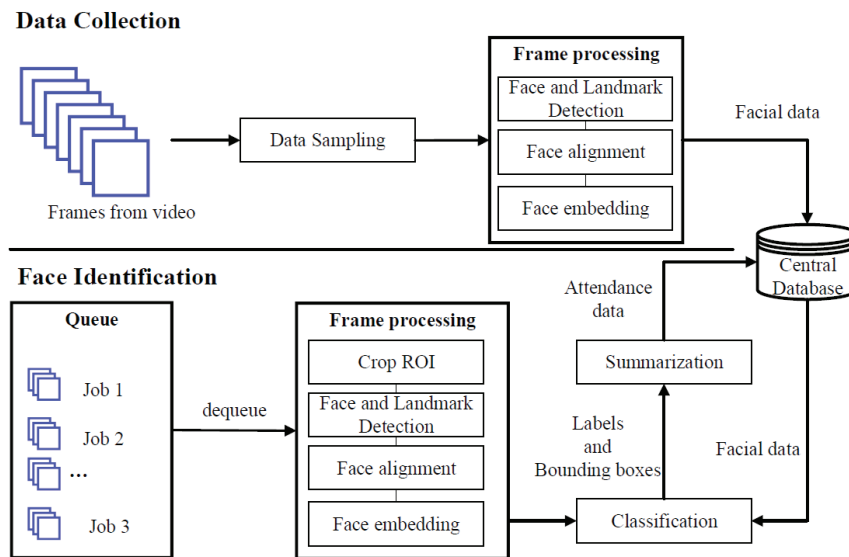


Figure 2. Components of face recognition module (Son *et al.*, 2020b).

to introduce robots (instead of classic CCTV) to identify abnormal activities in crowded places using CNN network and SVM for image classification task (Du, 2020). For training data UMN and PETS 2009 data set is used. Proposal showed improved accuracy and promising future implementations.

Gait is also an important feature for identification purposes and it is less affected by clothes, sunglasses, masks or other constraints that can impact recognition accuracy. Authors propose gait recognition method with CNN model and apply it using CASIA and OpenCV data sets. Results are applied to identify laboratory attendance with possible applications, for example, to record school attendance (Xu, Ren, & Nishide, 2020). Downside of gait recognition is that it is difficult to acquire data for recognition – capture the gait of the person.

For children identification, mostly face recognition is used. Face recognition has been applied to find missing children, support school safety and even social network activities of children (Oo & Oo, 2019). Children face long-term recognition is a challenging task, because children face is hard to recognize. Authors use three CNN for children face recognition to evaluate accuracy of networks, one VGG Face based and two VGG16 and ResNet50 based. Research authors conclude that MobileFaceNet data set provide best examples to train algorithms with improved accuracy (Oo & Oo, 2019). Children attendance to examinations to identify authenticity of person who takes the test has been also researched with implementation of deep learning functionality into schools CCTV systems (Othman & Aydin, 2019).

Some authors propose solutions that can be integrated with schools CCTV systems to record

attendance of lectures or school in general (Son *et al.*, 2020).

Figure 2 illustrates proposed components of face recognition module. Face identification takes a photo from a queue and passes it to identification. Frame processing crops only part of image, providing identification of face in the image. Authors used face-embedding technique for feature description. All crops are passed to vectorization and then to classification tasks. After that, a summarization algorithm is applied which allows making the final decision. Data collection part in Figure 2 is responsive to the frame extraction and then frame processing is done building feature vectors and storing them in the central database. To acquire training data set for this solution, authors built mobile application to record face video maximum 30 seconds long. Videos are uploaded to database server for further processing via web service.

In the next section, we propose children long term re-identification model that incorporates some of components mentioned in this section.

Results and Discussion

Long term identification conceptual model (Figure 3) was proposed in our first paper (Arhipova, Vitols, & Meirane, 2020b) related to children face identification. The conceptual model was divided into four steps – video feed processing, creation of biometric pattern and person's identification, supervised and unsupervised learning. Video feed processing uses CNN network for frame identification purposes.

During the recent development of Re-ID prototype, the proposed conceptual model was critically analyzed from the perspective of compatibility degree versus

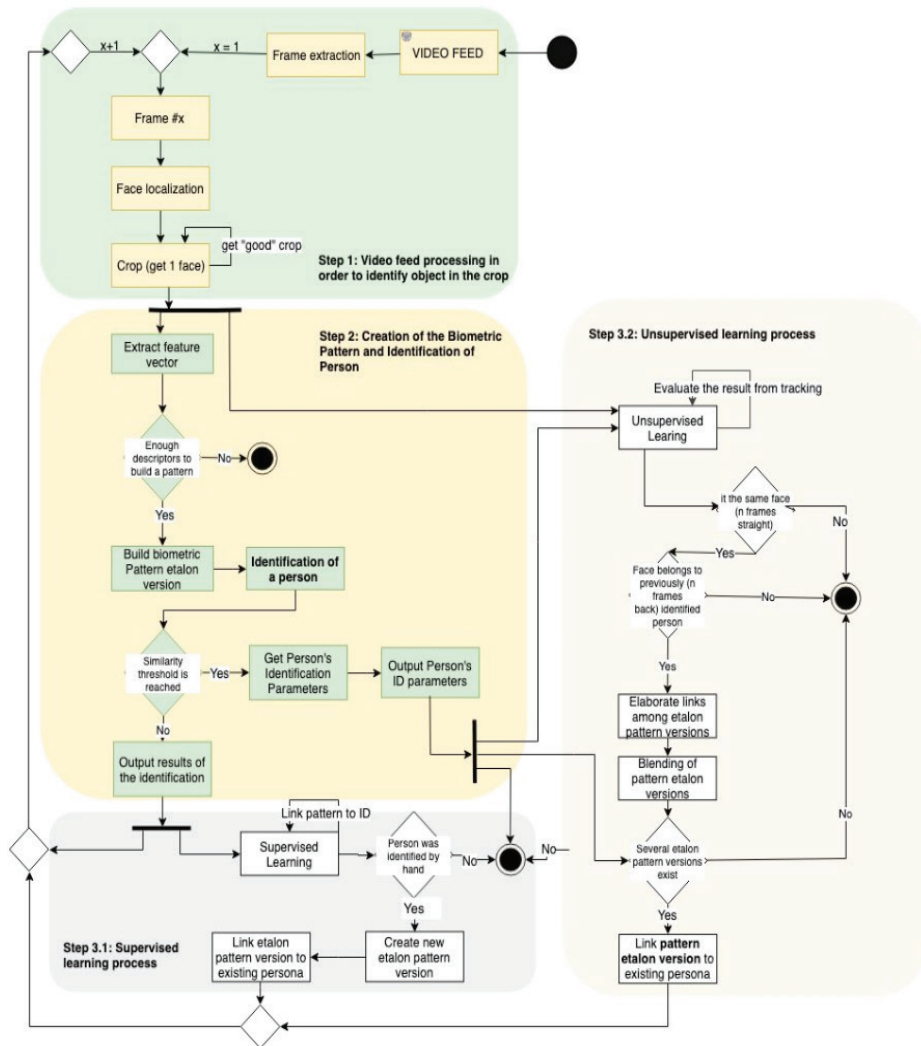


Figure 3. Re-ID conceptual model (Arhipova *et al.*, 2020b).

real life application. To start with, this conceptual model does not include any mentioning of knowledge base creation prior to identification process execution, as well as potential management functionality. The knowledge base must be created using children biometric and biographic data. In order to log the results of object detection and person identification, a registration process must be included. The process of logging object detection must be put at the end of the step 1, whereas person identification logging must be executed at the end of the step 2 regardless of identification success. Both of these logs must contain reference data, i.e. the person identified must also be detected before that. The prototype for children attendance implies automatic fixation of children attendance during a lesson; the model, however, does not contain such a process, and, therefore, must be improved. We suggest adding this process after the previously mentioned person identification logging process at the end of the step 2. Finally, any management processes, including creation

and management of user accounts, management of existing biometric and biographic data, are out of this model; however, during a development of real life application the development of mentioned processes must be elaborated.

Conceptual model improvement

There are four aspects of real life application of long-term identification important for successful implementation. These aspects refer to improvements of functionality and scalability of Re-ID system, and include object tracking, processing the cases of unexpected person, integration with external systems, implementation of video zones in educational institutions.

Video surveillance area in an educational institution

The space within educational institution is divided into several video surveillance zones (hereinafter – zones) – a particular classroom, a specific hallway, etc. that are surveilled, as a stream, by one or more video cameras. It is assumed that each stream is handled by separate logical model process, and it

should be possible to initiate multiple streams from a single workstation, i.e. corridor surveillance from a security workstation.

Zone is defined by (1) restricted space, i.e. classroom, hallway or adjacent grounds belonging to institution, (2) video surveillance devices, and (3) workstation handling the video surveillance stream, provided that one workstation is capable of handling multiple streams simultaneously.

To implement a new zone within institution the sufficient number of video surveillance devices must be installed and a workstation must be assigned to handle the video surveillance stream, produced by these devices.

Object tracking

The proposed conceptual model was intending the use of object tracking in order to provide consistency and accuracy for this object's identification. In the framework of Re-ID system, the object is a person that can be educational institution's student, employee or visitor. The object tracking is performed to fulfill two objectives: (1) to conclude that the person within particular image's coordinates is the same and (2) to conclude that the person detected has changed location, but the system can still tell that it is the same person. Achieving the first objective provides information for precise logging of object detection period, while the second gives possibilities to track person across all video-monitoring zones, i.e. tell if a student attended the correct class, or the same student was doing something suspicious outdoors on educational institution's grounds. The realization of the second objective is also one of the long-term identification's goals.

In addition, object tracking allows tracking the motion of a person, which may be important to assess the quality of education. Motion detection can process the motion of children's heads, arms and body language in order to determine if they give sufficient attention to teachers during classes, to detect any aggressive behavior and to detect any noticeable health conditions.

Identification of an unexpected person

To provide a secure learning environment, any unexpected person must be detected. There are risks concerning an unexpected person. An unexpected person that is attending educational institution may not be this institution's student, employee or attending parent/guardian, and is attending it with malicious intents, i.e. stealing, bullying and selling prohibited stuff. An unexpected person, that is this institution's student, is attending another group's class, thus potentially worsening learning process for other students.

We developed solutions to address these risks. Firstly, assuming that all educational institution's students and employees are registered in the knowledge base, any person that cannot be identified for a period is considered an unexpected person. Secondly, any student that is attending other group's class is considered an unexpected person. Thirdly, information about each detected unexpected person is sent to school's security personnel. Lastly, information about an unexpected person, which is not institution's student, employee or attending parent/guardian and which is attending educational institution without justification repeatedly, is sent to relevant authorities.

Improvements to the conceptual model consist of adding a new process that is responsible for delivering

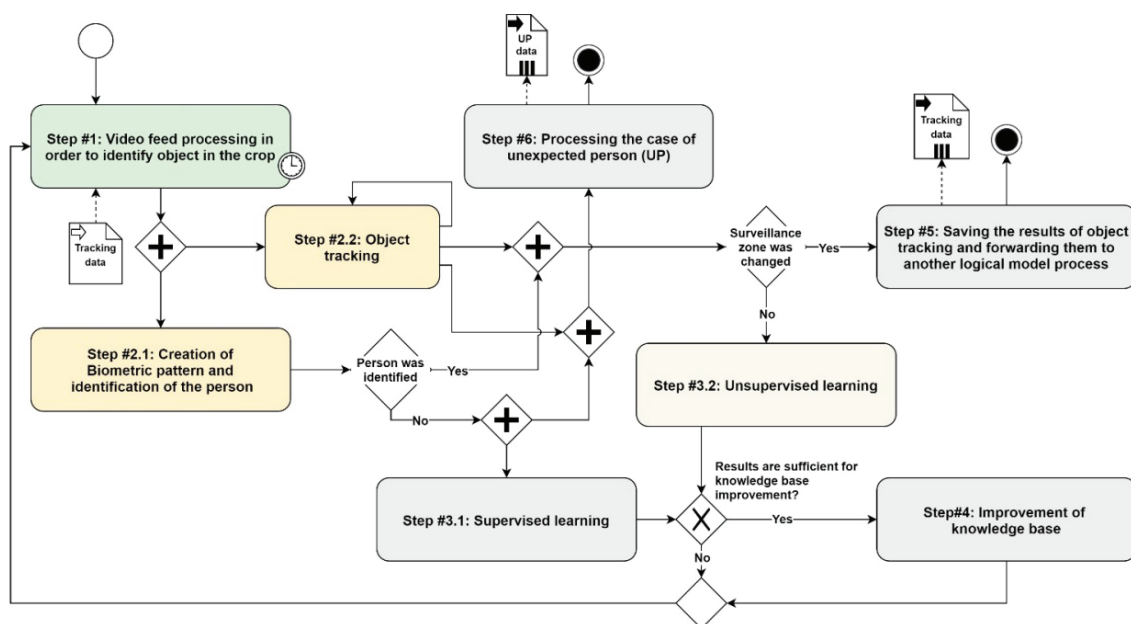


Figure 4. Improvements of conceptual Re-ID model.

information about a detected unexpected person to institution's security internal system.

Integration with external systems

The external systems are integrated into Re-ID system using input and output service gateways. We identified three systems related to educational institution: (1) educational institution's internal system, (2) educational institution management information system and (3) city's municipality information system.

Input data received from external systems include such data as (1) student's name, surname, personal number, birthdate, gender and photo, (2) student's social status, (3) information about student's parents/guardian. Student's social status can be used to classify students into groups and tailor educational process to particular group's needs. Input data about students received from the city's municipal system can be used to build a knowledge base, provided that this data is sufficient to establish the student's biographical and biometric identities.

Output data is generated automatically in order to reduce the needs for manual input, resulting in more efficient work for educational institution's employees. In the long term, the results of the identification give insight into whether the students are safe during classes or outside the educational institution.

We identified several output data, assuming that all students and employees are registered in the Re-ID knowledge base, and video-monitoring covers institution's classrooms, corridors and adjacent areas. These data include (1) attendance results that are logged in the institution's internal system's class attendance log, (2) the identities and total number of students who did not attend the institution on a daily/weekly/monthly basis, used for statistical analysis by institution's management information system, and (3) the biography data of students who have been identified doing suspicious activities, i.e. smoking, consuming alcohol, sent to institution's security system.

Model performance improvements and long-term re-identification

According to the scenarios described above, we developed a set of improvements (Figure 4) to the performance of the model.

These improvements are meant to address an object, respectively – a person, tracking across multiple surveillance zones, provided that a person is inbounds of overall surveillance coverage, enhancement of knowledge base using the results of supervised/unsupervised learning and realization of long-term re-identification.

Object tracking process is a repeatable process, executed after the person is first detected in a video stream. This process continues until a detected person

cannot be repeatedly detected within the original surveillance zone, i.e. a person leaves a classroom. In case the process was terminated due to the change of surveillance zone and the detected person was successfully identified, the tracking data and information about the identified person are provided to another logical model process, which in turn uses these data during the next processing iteration. If it was impossible to identify the detected person, the information about this person is processed according to unexpected person's processing normative/methods.

Knowledge base is enhanced using the results of supervised and unsupervised learning. These results include additional feature value for existing feature vectors, as well as completely new feature vectors. The execution of these processes is determined by the surveillance zone, i.e. there is no need to perform supervised learning for a sport hall, whereas unsupervised learning within it may result in ambiguous and imprecise data. The fact of person's identification successfulness is determinant for choosing correct learning approach. Supervised learning is executed in case a person was not identified, and includes manual input from an expert, whereas unsupervised learning is performed for the identified person, provided that the surveillance zone was not changed for a particular period. The change of surveillance zone leads to the change of video environment – background texture, brightness, light angle, etc., and, therefore, can hardly produce correlated data.

The aspects of object tracking and knowledge base enhancement within the process of identification play the major role for the long-term re-identification. Object tracking data allows linking multiple logical processes (streams) to track object in space and time, whereas enhancement of the knowledge base enables the storage of several versions of the biometric identity etalon versions, which allows the person to be identified even after a relatively long period of time and in another surveillance area.

Conclusions

1. From deep learning algorithms, Convolutional neural network (CNN) and its derivatives seem to be most applied as a core component for short term and long term re-identification solutions.
2. For children identification, mostly face recognition methods are applied which are usually integrated with CCTV systems or use data collected from CCTV cameras.
3. There are usually two options to train the networks – with existing data or data published online. From available data sets MobileFaceNet show promising results in training accuracy.
4. Previously proposed long-term re-identification model was incomplete and was limited in terms

of scalability. Enhancement in the aspects of unexpected person processing and surveillance zone management propels the model in terms of both scalability and functionality.

5. Enhanced model can be used as a basis for development of health surveillance system. This can be accomplished by using infrared cameras and CNN, trained accordingly.

Acknowledgements

The research leading to these results has received funding from the project ‘Competence Centre of Information and Communication Technologies’ of EU Structural funds, contract No. 1.2.1.1/18/A/003 signed between IT Competence Centre and Central Finance and Contracting Agency, Research No. 2.1 ‘Person long-period re-identification (Re-ID) solution to improve the quality of education’.

References

- Arhipova, I., Vitols, G., & Meirane, I. (2020). *Long Period Re-identification Approach to Improving the Quality of Education: A Preliminary Study*. DOI: 10.1007/978-3-030-39442-4_14.
- Bedagkar-Gala, A., & Shah, S.K. (2014). A survey of approaches and trends in person re-identification. *Image and Vision Computing*, 32(4), 270–286. DOI: 10.1016/j.imavis.2014.02.001.
- Chauhan, N.K., & Singh, K. (2019). A review on conventional machine learning vs deep learning. *2018 International Conference on Computing, Power and Communication Technologies, GUCON 2018*, 347–352. DOI: 10.1109/GUCON.2018.8675097.
- Du, Y. (2020). An anomaly detection method using deep convolution neural network for vision image of robot. *Multimedia Tools and Applications*. DOI: 10.1007/s11042-020-08684-1.
- Oo, S.L.M., & Oo, A.N. (2019). Child Face Recognition with Deep Learning. *2019 International Conference on Advanced Information Technologies, ICAIT 2019*, 155–160. DOI: 10.1109/AITC.2019.8921152.
- Othman, N.A., & Aydin, I. (2019). A Smart School by Using an Embedded Deep Learning Approach for Preventing Fake Attendance. *2019 International Conference on Artificial Intelligence and Data Processing Symposium, IDAP 2019*. DOI: 10.1109/IDAP.2019.8875883.
- Rothoft, V., Si, J., Jiang, F., & Shen, R. (2017). Monitor Pupils’ Attention by Image Super-Resolution and Anomaly Detection. *2017 International Conference on Computer Systems, Electronics and Control (ICCSEC)*, 843–847. Retrieved March 17, 2020, from <https://ieeexplore.ieee.org/document/8446759/>.
- Son, N.T., Anh, B.N., Ban, T.Q., Chi, L.P., Chien, B.D., Hoa, D.X., ... Khan, M.H.R. (2020). Implementing CCTV-based attendance taking support system using deep face recognition: A case study at FPT polytechnic college. *Symmetry*, 12(2). DOI: 10.3390/sym12020307.
- Vařeka, L. (2020). Evaluation of convolutional neural networks using a large multi-subject P300 dataset. *Biomedical Signal Processing and Control*, 58. DOI: 10.1016/j.bspc.2019.101837.
- Xu, Y., Ren, F., & Nishide, S. (2020). Using CNN’s gait recognition to strengthen laboratory safety supervision. *Proceedings of 2019 the 9th International Workshop on Computer Science and Engineering, WCSE 2019*, 181–188. Hong-Kong.

THEORETICAL SUBSTANTIATION OF THE COMPETITIVENESS OF ACADEMIC STAFF FROM THE PERSPECTIVE OF EDUCATIONAL SCIENCES

***Marina Troškova, Irena Katane**

Latvia University of Life Sciences and Technologies, Latvia

*Corresponding author's email: marina.troschkova@gmail.com

Abstract

The socio-economic changes brought about by globalisation, the internationalisation and digitalisation of higher education, as well as the current demographic situation in Europe and Latvia, raise the issue of the competitiveness of academic staff in the context of multicultural higher education. The aim of the study is to provide a theoretical basis for the competitiveness of academic staff in the view of educational sciences, respecting the different trends and based on the conceptual approaches in personal/specialist competitiveness research. The following research methods were used: study, analysis and evaluation of scientific literature (theoretical research method); reflection of personal experience (empirical research method). As a result of the theoretical research, two trends for the substantiation of the concept of competitiveness in the educational sciences were identified. The first trend: the competitiveness of a person is substantiated through transfers from economic and management science, with a particular emphasis on specialist marketability and employability as a significant manifestation of competitiveness. The second trend: according to the new paradigm of competitiveness in educational sciences, the competitiveness of a human as a person and as a specialist is based on the perspective of pedagogy and psychology. The research results led to the conclusion that there are three conceptual approaches in the methodology of competitiveness research: 1) qualitative approach: identifies and lists competitive personality traits and qualities; 2) functional approach: describes the competitive behaviour of a person or specialist; 3) structural approach: competitiveness is substantiated as a complex combination of personal/specialist qualities, identifying several structural components. All of these approaches are also characteristic to the research of competitiveness of academic staff. The following taxonomy should be respected in the substantiation of academic staff competitiveness: 1) substantiation of personal competitiveness; 2) substantiation of specialist competitiveness in the context of different industries; 3) the substantiation of the competitiveness of specifically academic staff in the context of the specifics of higher education.

Key words: academic staff, competitiveness, employment, globalisation, marketability, sustainability of higher education.

Introduction

Nowadays, the process of globalisation is causing socio-economic changes, as well as internationalisation and digitalisation of the higher education environment, creating new challenges for students and academic staff alike. The process of globalisation raises the issue of competitiveness of every country, each particular society and each individual, including academic staff and students, as emerging professionals at local, national and global levels. There is a need for continuous self-improvement, both as a person and as a specialist, by interacting with the ever-changing socio-economic environment as a specialist.

Experience has shown that the current demographic situation in Latvia, including the declining number of graduates and students in higher education, poses a threat to the competitiveness and sustainability of higher education institutions. Therefore, academic staff must change their thinking, must develop themselves professionally, thus ensuring their competitiveness, including the capacity for work and professional self-actualisation in these ever-changing conditions. Personal experience of the authors shows that the modern higher education environment is beginning to lose its international borders: 1) international study programmes are being developed as a result of inter-university cooperation; 2) exchange

of students and academic staff takes place within the framework of ERASMUS and other international cooperation agreements; 3) as the Latvian higher education environment becomes increasingly more open to international studies, more and more students from different countries are choosing programmes offered by Latvian higher education institutions; 4) the possibilities of distance education/e-studies in Latvian higher education are constantly expanding, which also attracts foreign students; 5) many foreign students wish to study in Latvia, while also getting acquainted with Latvian culture, including the language; at the same time, they need to communicate with the teaching staff in foreign languages which they are familiar with, so it is important to respect the culture and different needs of the foreign students studying in Latvia; 6) foreign academic staff increasingly more often wish to work in Latvian higher education institutions; 7) millennials begin their studies in Latvian higher education institutions. This sets new requirements for higher education. All these factors significantly raise the issue of competitiveness of the teaching staff in the multicultural environment of higher education.

There is another important factor that determines the topicality of academic staff competitiveness. That is, one of the goals of higher education is to promote the development of a competitive knowledge society,

ensuring the development of the competitiveness of young specialists, where the readiness for independent, creative and responsible professional activity is one of the indicators of competitiveness (Katane & Īriste, 2013; Сохач & Плугина, 2015).

In order to facilitate the development of teaching staff competitiveness, it must be possible to assess it. In order to develop the academic staff assessment methodology, it is necessary to develop the theoretical and methodological basis for academic staff competitiveness research from the point of view of educational sciences. It is necessary to identify the characteristics of academic staff competitiveness, its various manifestations in academic, research and organisational activities, thus developing a framework of indicators for assessing teaching staff competitiveness.

The topicality of the research on the competitiveness of educators, including academic staff, in the 21st century educational environment, is evidenced by several scientific publications (Baranova, 2012; Bogoyavlenskaya & Kliueva, 2013; Grebennikova & Rybkin, 2017; Katane, 2011; Донина & Стýрова, 2018; Плугина, 2016; Скляр, 2018; Сохач & Плугина, 2015; Харченко, 2014; Чупрова, 2004).

The aim of the study is to provide a theoretical basis for the competitiveness of academic staff in the view of educational sciences, respecting the different trends and based on the conceptual approaches in personal/specialist competitiveness research.

Materials and Methods

This study used the following theoretical research methods: study, analysis and evaluation of scientific literature, as well as an empirical research method: reflection of personal experience. The research was conducted in Latvia from 2019 to 2020.

The basis for the substantiation of academic staff competitiveness was the new competitiveness paradigm in educational sciences (Katane, 2010; Katane & Kalniņa, 2010).

As a result of the theoretical research, two trends for the substantiation of the concept of competitiveness in educational sciences were identified (Katane, 2011; Katane & Kalniņa, 2010).

- The first trend: the substantiation of personal competitiveness is formed by using transfers from economic and management sciences, and by comparing the professionalism and competency of a specialist to a commodity in labour market conditions, highlighting these sets of qualities as the advantages of competitiveness (Cummins, 2012; Grebennikova & Rybkin, 2017; Īriste, 2018; Katane, 2011; Katane & Īriste, 2013; Lowden *et al.*, 2011; Parker, 2008; Rothwell & Arnold,

2007; Swanepoel *et al.*, 2003; Sarfraz *et al.*, 2018; Teichler, 2007; Unger *et al.*, 2010; Митина, 2003; Широбоков, 2000).

- The second trend: the substantiation of personal competitiveness is based on a human-centric approach and humanist ideas and values in educational sciences and psychology (Grebennikova & Rybkin, 2017; Īriste, 2018; Katane, 2011; Katane & Īriste, 2013; Katane, Baltusite, & Katans, 2017; Katans, 2019; Андреев, 2004; Андреев, 2013; Митина, 2003; Суязова *et al.*, 2013; Холодцева, 2006; Шаповалов, 2006).

In educational sciences and psychology (in the methodology of these sciences) there are three conceptual approaches to researching human competitiveness (Īriste, 2018; Katane, 2010; Katane, 2011; Katane & Kalniņa, 2010): 1) qualitative approach: identifies and lists competitive personality traits and qualities; 2) functional approach: describes the competitive behaviour of the person or specialist; 3) structural approach: competitiveness is substantiated as a complex holistic combination of personal/specialist qualities, identifying several structural components.

The following theoretical research developments can be observed in the substantiation of academic staff competitiveness: 1) substantiation of personal competitiveness; 2) substantiation of specialist competitiveness, identifying the common characteristics of competitiveness and ways of manifestation in the context of different industries; 3) the substantiation of academic staff competitiveness, focusing on the specifics of professional activities and the higher education environment.

Results and Discussion

Transfers from Economic and Management Sciences to Educational Sciences in the Substantiation of Competitiveness of Specialists as Professionals

Competitiveness is one of the interests to scientists from different disciplines. Social sciences assess the competitiveness of the state and/or company. From the point of view of economic and management sciences, competitiveness is defined as the ability of a company, sector or country to sell and provide goods and services in the labour market, which arises from the needs of a globally integrated labour market and benefits from international sales (European Commission, 2019). According to experts, the level of competitiveness depends on a number of factors, including labour costs, regulatory burden, productivity, skills, innovation, infrastructure and other factors. The competitiveness of a specialist is often compared to that of a company, as specialists, including academic staff, offer and sell their skills,

knowledge and competences on the labour market (Cummins, 2012).

In several scientific publications, competitiveness is often replaced by the terms marketability and employability (Īriste, 2018; Katane, 2011b; Katane & Īriste, 2013; Katane, Baltusite, & Katans, 2017), as both marketability and employment are significant competitiveness indicators and manifestations. In the modern dynamic environment, which no longer offers long-term employment, the main goal of a specialist is to maintain and improve their attractiveness in the labour market (Parker, 2008). This, in turn, ensures the marketability of the specialist as a professional. Marketability of the educator/pedagogue, including academic staff, in the education environment, is determined by several factors: professionalism of the pedagogue, including competence; human qualities, including charisma; flexibility in thinking, actions and interactions with other people, including students and colleagues; ability to reconcile personal development goals with the development and sustainability goals of the educational environment in which they work (balance between ego-centred and eco-centred thinking and actions); the satisfaction of 'clients' of education – learners with the 'services' provided by the pedagogue, etc. (Katane, 2011b).

Russian scientists have also written about marketability as one of the manifestations of pedagogue competitiveness (Митина, 2003; Ширококов, 2000). For example, L. Mitina (Митина, 2003) emphasises the idea that a modern pedagogue is a competitive person if they are a marketable specialist in the labour market, who is capable of self-actualisation in their profession in a changing social, professional environment/work environment. S. Shirobokov (Ширококов, 2000) has also, when studying the competitiveness of teaching students as future teachers, emphasised the idea that teacher's competitiveness is primarily related to marketability in the labour market and marketability in society. How quickly and easily the goods can be sold depends on marketability. The same can be attributed to the marketability of a specialist, i.e. whether they are able to ensure their employment and how quickly they can find a new job if necessary (Parker, 2008). Thus, the concept of marketability is closely linked to the concept of employability.

The marketability of a specialist as an indicator of their competitiveness can be analysed and evaluated from two aspects: 1) internal aspect: the marketability arising from the specialist as a person, a professional in their field, which is determined by a set of specialist qualities that are highly valued in the professional field, including their various competences and competitive professional activities, which are both qualitative and productive, with expressions of creativity and innovation; 2) external aspect: the marketability

resulting from the labour market environment, which is determined by the real situation in the labour market, i.e. if there are open vacancies in the labour market, then every professional has environmentally determined marketability; however, due to changes of the external environment, i.e., in the case of a reduction in the amount of jobs, the marketability of a specialist in a particular profession is reduced, and therefore also their competitiveness in terms of their employability opportunities (Katane & Īriste, 2013). These findings can also be attributed to the marketability of academic staff as a manifestation of competitiveness.

Employability (just like marketability) can be substantiated and interpreted as a single structure, consisting of two parts: internal and external. The internal part contains knowledge, skills and competences, which an individual possesses. On the other hand, the external part depends on the environment, i.e. the labour market. Employability is seen as the ability to ensure one's employability (Grebennikova & Rybkin, 2017). It is important to emphasise here that employability includes several abilities: 1) ability to find their first job after graduating; 2) ability to retain the job; 3) ability to move from one job to another within the same organisation, taking on new duties, 4) ability to get a job in another organisation, if it is necessary, ensuring their career growth. Simultaneously, employability is not only the ability of professionals to find work in the labour market in circumstances of low demand for specific specialists, but also whether the pay at the new job is lower than what the specialist wants or whether it is below the industry average. If so, the newfound job is considered undesirable or unsustainable for their professional development. In other words, employability is the ability to find and retain a fulfilling job matching their competences and professional expertise, which is adequately valued and paid for by the employer.

From the aforementioned, the authors conclude that employability is also the ability to freely and flexibly move and adapt in the labour market, ensuring their mobility and career development, which is an important competitiveness indicator.

Scientist U. Teichler (2007) also suggests talking about increasing professional relevance of studies instead of graduate employability, where not only is the entry of graduates into the labour market important, but also the acquisition of such competences, skills and abilities which will ensure their professional mobility and long-term employability. The very definition of employability in the study of the Austrian scientist (Unger *et al.*, 2010) triggered discussions and was ambiguous. The study concluded that higher education must not be directed towards short-term labour market demands. Higher education institutions must provide

interdisciplinary skills, which are often referred to as key competences, and it is the acquisition of these skills that will ensure long-term employability, as professional skills become outdated too quickly.

Several publications (Rothwell & Arnold, 2007) have shown that scientists are interested in both the marketability and employability of graduate students, including young pedagogues, in the labour market after obtaining their higher education and professional qualifications. For example, K. Lowden et al (Lowden *et al.*, 2011) believe that employers should work together with higher education institutions to increase graduate marketability in the labour market. This is possible if employability skills are integrated into higher education programmes as the desired learning outcome. The study shows that employers value teamwork as well as the ability to solve problems. Recently the employability of graduates is viewed as a complex set of interrelated knowledge, skills and competences, which help individuals to become both safely and well-employed. There is also the opinion that employers particularly value general skills, analytical abilities and abilities that promote flexibility and adaptability. Employers highly value graduates being able to adapt to the organisational culture of the workplace, using their abilities and skills to develop in the organisation and to work with the new team. Graduates and specialists in general are expected to be proactive, be able to use advanced skills, including analysis and critical thinking.

Scientists (Safraz *et al.*, 2018), in their substantiation of employability, describe various employability skills, particularly highlighting those qualities, skills and abilities of a competitive specialist that are most valued by employers and which can be considered competitive advantages. For example, the ability to work in a team; ability to solve problems; communication; computer skills; analytical thinking; leadership; time management; interaction and organisational skills; interaction, including cooperation, skills; the ability to solve problems is valued highest. Specialists need these qualities, skills and abilities for work in all industries and at all levels of the organisational hierarchy.

Therefore, for students and graduates to be competitive as specialists, professionals of their industries, including being in-demand and employed in the labour market, academic staff must also be competitive, including being in-demand and very competent in their academic activities and professional specialisation.

Substantiation of Competitiveness of a Human as a Person and as a Specialist in Their Professional Field in the View of Pedagogy and Psychology

At the turn of the 20th and 21st century educational sciences shifted from the old competitiveness paradigm

to the new paradigm (Katane, 2010). According to the new paradigm, a competitive individual competes with themselves in their self-development: with their own weaknesses, inability and unwillingness. They are able to cooperate with others, viewing competitors as potential partners for cooperation. According to the new paradigm, a competitive person is creative, flexible, capable of making decisions, able to take responsibility for their decisions and consequences of their actions, able to solve non-standard situations and problems, capable of self-development and self-actualisation in a constantly changing environment. Such people view changes as new opportunities rather than threats, because they are able to take reasonable risks, master new things by taking on various challenges which arise during processes of change, are capable of changing themselves and changing their environment with their own innovations. Such specialists are respected by others and are in demand in the labour market.

The Russian academic V. Andreyev (Андреев, 2013), the founder of 'competitionology' (interdisciplinary educational science on human competitiveness), emphasises several ideal qualities of a competitive person: motives and orientation of values; moral, civil, intellectual and business values; character traits, communication and organisational skills, all of which influence the activities and behaviour of the person. V. Shapovalov (Шаповалов, 2005) also relies heavily on the qualitative approach when describing personal competitiveness. He emphasises that competitiveness is a socially-orientated personality system, which includes abilities, character traits and other qualities, for example, self-confidence based on their own abilities and possibilities (Холодцева, 2006).

The substantiation of academic staff competitiveness also highlights a number of qualities that are characteristic of competitiveness: flexibility, mobility, adaptability, psychological readiness to receive and apply new information, learn new technologies, high levels of independence and accountability, high stress tolerance, need for success in professional activities, personal qualities of a humane person, various abilities and competences (Плугина, 2016; Чупрова, 2004).

The functional approach in competitiveness research is characteristic to those scientists who try to research and describe human competitive behaviour. For example, a competitive specialist is a specialist, whose work is equally high quality and productive regardless of whether they are being watched by someone from the management team. This demonstrates a high level of professionalism, which is an essential component of competitiveness (Katans, 2019). It is very important to note that a

competitive specialist is someone who can (Katane, Baltusite, & Katans, 2017; Katans, 2019): 1) self-actualise in a constantly changing environment; 2) not only achieve success, but also be able to overcome failures in the process of development, finding new strength within themselves for new development. These findings are largely based on the synergistic approach in psychology and educational sciences, as human development is a multi-cyclical and non-linear process. One of the most important characteristics of competitive behaviour is the need of a person for self-actualisation (Митина, 2003), which A. Maslow wrote about (Maslow, 1968) when researching self-sufficient personalities. This need becomes a powerful motivator for professional self-development. R. Miller and V. Frankl (cited in Холодцева, 2006) also believed that competitive behaviour is based on a developed need for success. Human health is an important indicator of competitiveness, as it is an important factor that significantly influences the process of self-actualisation. The significant features of academic staff competitive behaviour are: 1) Continuous reflection on one's pedagogical activity and professionalism, readiness and ability to constantly seek education and self-educate throughout their entire professional life (Чупрова, 2004); 2) competently organising the study process, facilitating the formation and development of each student's personality as a future specialist, aiding the development of their moral and intellectual self-development motivation management system (Сохац & Плугина, 2015); 3) active teaching staff position and readiness to improve one's skills in working with scientific, methodological and teaching frameworks; professional and personal self-development, readiness to learn innovative methods; incorporating creativity in work with students; a holistic and systemic approach to ensuring a scientific and methodological basis; development of a scientific methodological orientation; methodological competence of the teaching staff and involvement in the development of the scientific and methodological framework for studies (Харченко, 2014). In her doctoral thesis S. Baranova (Baranova, 2012) emphasises that competitive academic staff is aware of its resources, potential for development and professional development, self-searching and self-evaluation become the basis for further education.

The structural approach is characteristic to those researchers, who substantiate and describe competitiveness as a complex multicomponent structure (Īriste, 2018; Kalnina, 2010; Katane, 2010; Katane, 2011; Katane & Kalniņa, 2010; Митина, 2003; Шаповалов, 2005) or multilevel hierarchical structure (Grebennikova & Rybkin, 2017; Katans, 2019), creating competitiveness structure models. For example, L. Mitina (Митина, 2003) highlights the following components in the competitiveness

structure: personality direction, competence and flexibility. Other researchers also emphasise that competence is an important component of a specialist's competitiveness structure (Īriste, 2018; Katane, 2011; Katans, 2019), which simultaneously is also significant capital of a human (Bogoyavlenskaya & Kliueva, 2013). It is important to facilitate the development of each specialist's competence, including professional competence and its level, as this will also have a significant impact on the development of competitiveness in general. In the model developed by V. Grebennikova and A. Rybkin (Grebennikova & Rybkin, 2017), competitiveness consists of three basic levels: 1) general level – competitiveness as a scientific category in a broad sense, which includes the competitiveness of the society, economy, organisation and humans; 2) special or specific level: the object or subject of competitiveness is specified by focusing on the specific subject of the research, for example, competitiveness of a company or person; 3) individual or personal level: the competitiveness of a specialist of a specific industry, for example, the competitiveness of a pedagogue, which is affected by all the previously mentioned competitiveness levels, and vice-versa – the competitiveness of the pedagogue ensures the competitiveness of the educational institution, in which they work, as well as of the entire society in the specific socioeconomic circumstances. The educator's level of competitiveness describes the ability to handle and accept challenges. Based on the structural approach, the author (Katane, 2011) of the article has developed the structural model of an educator's competitiveness, identifying five components of competitiveness: 1) component of personality direction, including professional direction; 2) component of self-conception; 3) component of self-regulation and self-management, including volition, emotional intelligence and personality's flexibility; 4) component of competences, including professional competences; 5) component of individual qualities (for example, intelligence, charisma, sense of humour, creativity, different characteristic features, health, etc.), and the basis for the development of an educator's competitiveness is experience.

It can therefore be concluded that research of academic staff competitiveness already has a significant theoretical and methodological basis, and all three conceptual approaches are being used. At the same time, it is important to focus on the specifics substantiating academic staff competitiveness, as the specifics of academic, research and organisational activities, as well the specifics of the higher education environment allow one to distinguish the unique aspects through which the description of teaching staff competitiveness can differ from the general description of competitiveness of any person, industry

or industry specialist. This outlines the prospects for future research.

Conclusions

1. The socio-economic changes brought about by globalisation, the internationalisation and digitalisation of higher education, as well as the current demographic situation in Europe and Latvia, raise the issue of the competitiveness of academic staff in the context of multicultural higher education.
2. The substantiation of academic staff competitiveness can be based on the interdisciplinary approach, using transfers from economic and management sciences. The marketability and employability of specialists in the labour market should be considered significant indicators and manifestations of competitiveness.
3. In pedagogy and psychology, the research of human competitiveness takes place under the influence of the new paradigm. There are three conceptual approaches (qualitative, functional and structural approach) to the competitiveness research of a person and specialist, including pedagogue/academic staff as a professional. In the context of competence and self-management, the substantiation of teaching staff competitiveness highlights the need for continuous self-development and professional development, ensuring self-actualisation. The method for self-development and self-actualisation is lifelong and lifewide education.
4. It is important to not only rely on the available general and common approaches to the research of competitiveness of various industry specialists, but to also focus on the unique manifestations of competitiveness and competitive behaviour of academic staff, because academic, research and organisational activities bring their own specificity to the research of academic staff competitiveness. Therefore, the following taxonomy should be respected in the substantiation of academic staff competitiveness: 1) substantiation of 'personal competitiveness'; 2) substantiation of 'specialist competitiveness' in the context of different industries; 3) the substantiation of specifically academic staff competitiveness in the context of the specifics of higher education.

References

- Baranova, S. (2012). Augstskolu docētāju profesionālā pilnveide tālākizglītībā (Higher Education Institution Teachers' Professional Development in Continuing Education). Doctoral dissertation. Riga: Latvijas Universitāte. (in Latvian).
- Bogoyavlenskaya, D.B., & Kliueva, O.A. (2013). To the Problem of Competitive Personality Concept. *Procedia – Social and Behavioral Sciences*. 80, 360–368. DOI: 10.1016/j.sbspro.2013.08.580.
- Cummins, E. (2012). *Senior European Experts Competitiveness in the European Union – Senior European Experts*. Brussels. Retrieved December 8, 2019, from <https://senioreuropeanexperts.org/paper/competitiveness-european-union>.
- European Commission. (2019). *Competitiveness. International Cooperation and Development*. Brussels. Retrieved December 12, 2019, from https://ec.europa.eu/europeaid/sectors/economic-growth/private-sector-development/competitiveness_en.
- Grebennikova, V.M., & Rybkin, A.D. (2017). Analysis of the essential characteristics of the phenomenon of 'competitiveness'; in the aspect of preparing a contemporary teacher. *Education and Pedagogical Sciences*, 9 (2), 178–184. DOI: 10.17748/2075-9908-2017-9-5/2-178-183.
- Īriste, S. (2018). *Prospective Managers' of Hospitality Business Competitiveness Evaluation and Development promotion in the Dual Study Environment of Higher Education Institution*. Summary of the Doctoral Thesis. Jelgava: LLU.
- Kalnina, I. (2010). *Promotion and Evaluation of the Development of Secondary School Pupils' Competitiveness within the Environment of Non-Formal Commercial Education*. Summary of the Doctoral Thesis. Jelgava: LLU.
- Katans, E. (2019). *Programmētāju profesionālās attīstības veicināšana mācīties spējīgā IT uzņēmumā zināšanu pārvaldības skatījumā* (Promoting the Professional Development of Programmers in a Learning IT Company from the Perspective of Knowledge Management). Jelgava: LLU. (in Latvian).
- Katane, I., Baltusite, R., & Katans, E. (2017). Theoretical background for investigation and promotion of engineers competitiveness in education. In Proceedings of the 16th International Scientific Conference 'Engineering for Rural Development', Vol. 16, Jelgava: LLU TF, 824–831.
- Katane, I. (2010). Competitiveness of Personality as a New Concept in Modern Education and Pedagogy Science. In Proceedings of the 9th International scientific Conference 'Engineering for Rural Development', May 27–28, 2010, Vol. 9, (pp. 327–334). Jelgava: LLU.

- Katane, I. (2011). Philosophic Methodological Bases for Evaluation of Educator's Competitiveness. In Proceedings of the 17th Annual International Scientific Conference 'Science for Rural Development', May 18–20, 2011, Vol. 2, (pp. 218–224). Jelgava: LLU.
- Katane, I., & Īriste, S. (2013). Students' as Prospective Hospitality Specialists' Competitiveness in Theory and Practic. In Proceedings of the International Scientific Conference 'Society. Integration. Education', May 24–25, 2013, Vol. 1, (pp. 119–129). Rēzekne: RA.
- Katane, I., & Kalniņa, I. (2010). Skolēnu konkurētspējas attīstība neformālās komercizglītības vidē (Development of Pupils' Competitiveness in the Environment of Non-Formal Commercial Education). Jelgava: LLU. (in Latvian).
- Maslow, A. (1968). *Toward a psychology of being*. 2nd Edition. USA: Van Nostrand Reinhold Company Inc.
- Lowden, K., Hall, St., Dr Elliot D., & Lewin, J. (2011). *Employers' perceptions of the employability skills of new graduates*. London: University of Glasgow SCRE Centre and Edge Foundation.
- Parker, G. (2008). *Capitol Investments: Marketability of Political Skills*. USA: University of Michigan Press.
- Rothwell, A., & Arnold, J. (2007). Self-perceived employability: Development and validation of a scale. *Personnel Review*, Vol. 36–1, (pp. 23–41).
- Sarfraz, I., Rajendran, D., Hewege, C., & Mohan, M.D. (2018). An exploration of global employability skills: A systematic research review. *International Journal of Work Organisation and Emotion*, Vol. 9–1, (pp. 63–88). Melbourne: Swinburne University of Technology.
- Swanepoel, B., Erasmus, B., Van Wyk, M., & Schenk, H.W. (2003). *South African Human Resource Management: Theory & Practice*. Cape Town: Juta & Co Ltd.
- Teichler, U. (2007). Studium und Berufschancen: Was macht den Unterschied aus (Studies and career opportunities: what makes the difference). *Beiträge zur Hochschulforschung*, 29(4), 10–31. (in German).
- Unger, M., Zaussinger, S., Thaler, B., Dibiasi, A., Grabher, A., Terzieva, B., Litofcenko, J., Binder, D., Brenner, J., Stjepanovic, S., Mathä, P., & Kulhanek, A. (2010). *Bericht zur sozialen Lage der Studierenden: Studierenden - Sozialerhebung 2009* (Report on the Social Situation of Students: Students – Social Survey 2009). Wien: Institut für Höhere Studien (IHS). (in German).
- Андреев, В.И. (2004). Учебный курс для творческого саморазвития конкурентоспособности (Training Course for Creative Self-development of Competitiveness). Казань: Центр инновационных технологий. (in Russian).
- Андреев, В.И. (2013). Конкурентология (Competitiveness Science). Казань: Центр инновационных технологий. (in Russian).
- Донина, И.А., & Стырова, Е.А. (2018). Конкурентоспособность педагога как тенденция развития современного образования (The competitiveness of the teacher as a trend in the development of modern education). Санкт – Петербургский Образовательный Вестник, 29–34. (in Russian).
- Митина, Л.М. (2003). Психология развития конкурентоспособной личности (Developmental Psychology of the Competitive Personality). Москва: МПСИ (in Russian).
- Плугина, М.И. (2016). Детерминанты профессионального становления преподавателя высшей школы в современных социокультурных условиях (Determinants of Professional Formation of Teachers in Contemporary Social Cultural Environment of Higher Education). Вестник РУДН, Педагогика и психология, 96–104. (in Russian).
- Скляр, Е.С. (2018). Конкурентоспособность преподавателя ВУЗа как одно из условий повышения качества образовательных услуг (Competitiveness of a university teacher as one of the conditions for improving the quality of educational services). Иннов: электронный научный журнал. Retrieved December 11, 2019, from https://www.innov.ru/science/economy/konkurentosposobnost-prepodavatelya/?fbclid=IwAR2pzB5AIUCe_F37V0eo7hzOREc6TSADVa-VrEouf-83-nG_tid8hdJ0e2E. (in Russian).
- Сохач, А.Я., & Плугина, М.И. (2015). Конкурентоспособный преподаватель – конкурентоспособный выпускник ВУЗа (A competitive teacher – a competitive graduate of university). Науки об образовании. Retrieved December 13, 2019, from <https://cyberleninka.ru/article/n/konkurentosposobnyy-prepodavatel-konkurentosposobnyy-vypusknik-vuza/viewer>. (in Russian).
- Суязова, Л.В., Мустафина, Д.А., Ребро, И.В., & Рахманкулова, Г.А. (2013). Структура конкурентоспособности будущего инженера в машиностроении (The Structure of Competitiveness of an Intended Engineer in Mechanical Engineering). Международный студенческий научный вестник. Retrieved November 30, 2019, from <https://www.eduherald.ru/ru/article/view?id=70> (in Russian).
- Харченко, Л.Н. (2014). Проектирование программы подготовки преподавателя высшей школы (Projecting Programmes to Prepare Teachers in Higher Education Institutions). Москва: Литагент Директмедиа. (in Russian).

- Холодцева, Е.Л. (2006). Конкурентоспособность в системе разноуровневых характеристик личности специалистов социальной сферы (Competitiveness in the system of multilevel personality characteristics of specialists in the social sphere). Диссертация. Барнаул: БГПУ. (in Russian).
- Чупрова, О.Ф. (2004). Формирование конкурентоспособности личности будущего учителя в процессе экспертно-аналитической деятельности (Formation of the Competitiveness of the Personality of the Prospective Teacher in the Process of Expert-Analytical Activity). Диссертация. Иркутск: Иркутский Государственный университет. (in Russian).
- Шаповалов, В.И. (2005). Конкурентоспособность личности в парадигме инновационного педагогического менеджмента (Personality competitiveness in the paradigm of innovative educational management). Ярославский Педагогический Вестник. Retrieved December 13, 2019, from <https://cyberleninka.ru/article/n/konkurentosposobnost-lichnosti-v-paradigme-innovatsionnogo-pedagogicheskogo-menedzhmenta/viewer>. (in Russian).
- Широбоков, С. (2000). Оценка качества подготовки конкурентоспособного специалиста в педагогическом вузе (Assessment of the quality of training a competitive specialist in a pedagogical university). Диссертация. Омск: Отслый государственный университет. (in Russian).

CHANGES IN THE ENGINEERING STUDENTS' PROCRASTINATION SELF-EVALUATION WITHIN THE EXPERIMENTAL APPROBATION OF CAREER EDUCATION PROGRAM

*Aleksandra Jerkunkova, Irena Katane, Regina Baltusite

Latvia University of Life Sciences and Technologies, Latvia

*Corresponding author's email: aleksandra.jerkunkova@llu.lv

Abstract

One of the modern education problems being investigated is a phenomenon of student procrastination and minimisation of its influence on achievement of career goals. A transformative pedagogical experiment was carried out involving 1st year engineering students of Latvia University of Life Sciences and Technologies during the 2018/2019 academic year. The aim of the transformative pedagogical experiment was to promote the reduction of student procrastination levels and achievement of their goals by practical experimental approbation of a career education program. During the experiment, self-evaluation of student procrastination was performed before and after the implementation of the career education program. The methodology included 20 indicators of procrastination self-evaluation. The program included three topic-based parts: 1) understanding and setting student career goals; 2) defining procrastination levels and factors; 3) the influence of procrastination minimisation on career goals' achievement. The study results allowed to conclude that due to the career education program elaborated and implemented in practice, substantial changes in student procrastination self-evaluation took place during the transformative pedagogical experiment. There was a significant difference in student procrastination levels before and after the transformative pedagogical experiment. The study results demonstrated that the elaborated and experimentally implemented career education program is valid and can be further used for minimisation of student procrastination, it can contribute to career goals' achievement and for the reduction of early discontinuation of studies and dropping out of university as there is a correlation between procrastination and dropout phenomena.

Key words: career development guidance; career education program; higher education; procrastination; students' self-evaluation.

Introduction

One of the modern education problems being investigated is a phenomenon of student procrastination and reduction of impact on career goals' achievement.

According to scientific publications (Klingsieck, 2013; Silkāne & Austers, 2017; Steel, 2007), procrastination is characterised as a conscious delay of planned, essential and personally important activities regardless of the fact that negative consequences of such delay will prevail over the positive ones.

Unfortunately, a procrastinator in the result of procrastination is not able to plan time and perform self-management of tasks. The authors' experience shows that undesirable consequences of student procrastination include failure to complete independent study assignments and submit the assignments in a timely manner, non-attendance of lectures, worsening of mutual relations among students and teaching staff, deterioration in student attitude towards studies and change of their future careers, inability to adapt to university study environment. As a result of procrastination, students accumulate both academic and financial debts. All this can become a reason of early discontinuation of studies and dropping out of university.

Therefore, nowadays the research about procrastination including procrastination among university students remains a topical issue (Cheung & Ng, 2019; Eisenbeck, Carreno, & Ucles-Juarez,

2019; Fernie *et al.*, 2019; Kljajic & Gaudreau, 2018; Silkāne, 2018; Wessel, Bradley, & Hood, 2019).

The phenomenon of procrastination occurs rather frequently and is not considered as a new, recently discovered phenomenon (Ellis & Knaus, 1977; Wistrich, 2008), as it has been recorded that 90–95% of population have experienced procrastination at least once, which means that almost every individual has delayed or postponed a task. For chronic procrastinators, procrastination is some kind of self-defence mechanism for avoiding difficulties, failures, stress in relation to deadlines of work submission, a negative emotional experience, etc. (Ferrari, Barnes, & Steel, 2009; Ferrari *et al.*, 2007), as they are accustomed to postpone important tasks without any real need and reason in various life situations and spheres.

Scientists T.P. Tibbett and J.R. Ferrari (Tibbett & Ferrari, 2015) believe that a delay in task performance and decision making can be determined by various reasons and procrastination is some kind of a final result that is more based on a coincidence of various factors rather than on definite character traits of a certain person, yet they also matter. Scientists emphasise that typical procrastinators usually delay completion of tasks purposefully due to their own irrational reasons, at the same time being concerned about the delay.

However, the results of researches on procrastination carried out by scientists P. Steel and

K.B. Klingsieck, (Steel, 2007, 2010; Klingsieck, 2016) show that: 1) if the level of procrastination is permanent in terms of time and different situations, there is a reason to consider that procrastination is a personal trait; 2) there is a close correlation between procrastination and dysfunctional impulsivity, poor self-direction and self-control.

Several researches have been carried out in recent years by the scientists D.E. Gustavson, *et al.*, (2014) who carried out an in-depth study of possible relation between procrastination and impulsivity. Previous studies discovered moderate and positive correlation between procrastination and impulsivity. However, little was known about the reasons why these two constructs are connected. In the research done in 2014, the above mentioned scientists used a behaviour-genetics methodology to verify three forecasts based on a hypothesis that procrastination arises as a by-product of impulsivity: 1) procrastination is heritable; 2) both traits have substantial genetic variations; 3) the ability of goal management is an important part of this common variation.

V. Silkane (Silkane, 2018) points out that there are various types of procrastination: 1) active and passive procrastination; 2) procrastination of urge and avoidance; 3) procrastination of decision making.

The phenomenon of procrastination affects many areas of people's life including setting and achieving their career goals. The problem of procrastination that may cause a dropout is especially topical for the 1st year university students, and it is directly related to the process of adaptation to a new study environment. Higher education environment is distinctly different from educational environment at schools. The proportion of independent studies is bigger in the higher education environment, the role of self-management competence becomes more significant, including the aspect of time management. Since procrastination is closely related to self-management (including self-regulation and self-control), the following inference can be drawn: if the level of student self-management in terms of studies and career increases, the level of procrastination will decrease. To a great extent, it will allow students to avoid impulsive, sometimes ill-considered decisions in relation to early discontinuation of studies and dropping out of university.

To solve the problem of student procrastination in higher educational institutions by contributing to the reduction of their procrastination level, it is important to provide career development guidance by informing, educating and consulting students on the problem of procrastination, its consequences, examples, dropout risk.

The students' career development guidance (including career education and counselling) in

university is one of higher education sustainable development priorities. This research problem is currently being investigated by a number of scientists (Carliner *et al.*, 2015; Ford, 2015; Helyer & Lee, 2014). The results of these researches, along with various career theories e.g., Gottfredson's Theory of Circumscription and Compromise; Holland's Theory of Vocational Personalities in Work Environment; Theory of Work-Adjustment, Self-concept; Theory of Career Development etc. (Brown & Lent, 2017; Dahling & Librizzi, 2015; Luke & Redekop, 2019; Neff, 2017; Taber & Blankemeyer, 2015) have become a methodological basis of an elaborated and experimentally approved career education program whose aim was to reduce student procrastination level and contribute to the achievement of career goals.

Within the framework of career development guidance, the essence of procrastination was explained to the students; they found out about themselves by analysing individual strengths and weaknesses, learned to manage personal life including their studies within higher education environment.

The aim of the research: to promote the reduction of student procrastination levels and achievement of their goals by practical experimental approbation of the career education program.

Materials and Methods

The research was carried out during the 2018/2019 academic year at Latvia University of Life Sciences and Technologies. It was a transformative experiment (a specific case study). Within the framework of the students' career development guidance the developed career education program for engineering students 'Reducing the Impact of Procrastination and Career Goals' Achievement' (10 academic hours) was experimentally approbated. The experimental group consisted of ten 1st year students of engineering.

The aim of the program was to reduce the level of student procrastination and to promote their career goals' achievement.

The program included three topic-based parts.

- Understanding and setting student career goals (3h).
- Defining procrastination levels and factors (2h).
- The influence of procrastination minimisation on career goals' achievement (5h).

The elaborated program had a number of functions: informing, educating, promoting self-understanding, counselling.

Various methods of study have been used during the experiment: lectures, discussions, problem-based studies (independent group work) and individual work during workshops and practical training.

Table 1

The Table of Procrastination Results Calculation (Buliņa, 2011)

Procrastination level	The amount of points acquired
Level 1. Low	... ≤ 51
Level 2. Average	52 ≤ 63
Level 3. High	64 ≤ ...

Various methodologies are used by scientists in their researches for defining procrastination levels, for example:

- General Procrastination Scale (Lay, 1986);
- Adult Inventory of Procrastination (McCown, Johnson, & Petzel, 1989).
- Decisional Procrastination Scale (Wieland *et al.*, 2018);
- The Active Procrastination Scale (APS) (Choi & Moran, 2019).

During the experiment, self-evaluation of student procrastination was performed before and after the implementation of the career education program by using a 'General Procrastination Scale' methodology (Lay, 1986), which is adapted and experimentally approved in Latvia by R. Buliņa (Buliņa, 2011). The methodology includes 20 indicators of procrastination self-evaluation. In accordance with each of these 20 indicators, the signs of procrastination were self-assessed based on a 5-point scale; the scores were as follows: very relevant (5 points); rather relevant (4 points); neither relevant nor irrelevant: neutral (3

points); rather irrelevant (2 points), not relevant at all (1 point). The procrastination level for each participant has been defined individually in accordance with the amount of points acquired. By using this methodology, three procrastination levels can be distinguished: low, average, high (Table 1).

The following research methods were used during the transformative experiment: 1) data obtaining: survey (questionnaires); 2) data processing: descriptive statistics (Σ of assessment points; mathematical values of procrastination level, differences between self-evaluation of procrastination, differences between procrastination levels); conclusive statistics, by using Wilcoxon Test (SPSS 21.0).

Results and Discussion

After the pedagogical experiment, the student procrastination self-assessments acquired before and after the elaborated career education program approbation were summarized.

The assessment amounts were defined by calculating them for each student individually in

Table 2

The Results of the Student Procrastination Level Self-Evaluation Before and After the Career Education Program Approbation: Descriptive Statistics

Students	Self-evaluation of procrastination (Σ)		Differences	Procrastination level		Differences
	Before	After		Before	After	
	58	59	+1	2	2	0
	56	51	-5	2	1	-1
	53	46	-7	2	1	-1
	45	39	-6	1	1	0
	54	55	+1	2	2	0
	57	56	-1	2	2	0
	52	45	-7	2	1	-1
	51	44	-7	1	1	0
	56	48	-8	2	1	-1
	53	52	-1	2	2	0
	Positive differences:		2	Positive differences:		0
	Negative differences:		8	Negative differences:		4
	Ties:		0	Ties:		4

Table 3

The Results of the Wilcoxon Test: Conclusive Statistics

N	Data processing hypotheses	The obtained results	Conclusions
1.	$H_0: SPPNS_1^* = SPPNS_2^*$ $H_1: SPPNS_1 \neq SPPNS_2$	$p = 0.021 < \alpha = 0.05$	There is a significant difference among the student procrastination self-assessments sums before and after the experiment.
2.	$H_0: SPL_1^* = SPL_2^*$ $H_1: SPL_1 \neq SPL_2$	$p = 0.046 < \alpha = 0.05$	There is a significant difference among the student procrastination self-assessments levels before and after the experiment.

*Abbreviation key

SPPNS₁: The sum of students' procrastination self-assessments before the experiment.

SPPNS₂: The sum of students' procrastination self-assessments after the experiment.

SPL₁: The level of students' procrastination self-assessments before the experiment.

SPL₂: The level of students' procrastination self-assessments after the experiment.

accordance with 20 procrastination indicators (in 5 points scale), summarizing all the obtained points. Therefore, the maximum possible score in the survey for each student was 100 points.

The level of procrastination was defined based on the table for procrastination results calculation (Table 1). The results of procrastination levels calculated in the table are placed on the nominal scale in accordance with the following alignment: High (Level 3) = 3; Average (Level 2) = 2; Low (Level 1) = 1 (Table 1; Table 2).

During the initial mathematical processing of the data obtained, descriptive statistical data were acquired (Table 2).

In accordance with the methodology for defining the procrastination level, the lower the self-assessment obtained, the better.

The values of the obtained self-assessment sums (Table 2) demonstrate that the self-assessments of all 10 students changed: the self-assessment of procrastination of 8 students reduced, while the self-assessment of 2 students increased.

Before the approbation of the elaborated career education program, the level of procrastination was defined as average for 8 of 10 students, and 2 students had a low procrastination level. In its turn, after the experiment, the obtained results of the research demonstrated that 4 students only retained the average procrastination level, while 8 students had a low procrastination level. The results allowed to conclude that the self-assessments made by 4 of 10 students experienced outstanding changes, as their self-assessments reduced from the average to low procrastination level (Table 2).

In order to define whether any statistically significant changes in self-evaluation of procrastination took place during the pedagogical experiment, the amounts of self-evaluation obtained before and after the approbation of the career education programme called 'Reducing the Impact of Procrastination and

Career Goals' Achievement' and the procrastination levels were compared.

The data were processed by using the Wilcoxon Test in the SPSS 21.0 software application, obtaining the results of conclusive statistics (Table 3).

The conclusive statistic results show that due to the career education program elaborated and implemented in practice, significant changes in the self-evaluation of student procrastination took place during the transformative pedagogical experiment. There are significant differences between the students' procrastination levels before and after the experiment as well (Table 3).

Discussion. Theoretical studies results show that procrastination is one of the reasons of the students' dropout. The correlation between procrastination and dropout phenomena is confirmed by the results of studies that can be found in various scientific publications (Bardach *et al.*, 2019; Baulke, Eckerlein, & Dresel, 2018; Grau & Minguillon, 2013; Gubbels, Put, & Assink, 2019). This means that during the transformative experiment, along with the minimisation of the influence of procrastination phenomenon on the participants of the experiment (1st year engineering students), the dropout risk was minimised as well.

Conclusions

1. There are significant differences in self-evaluation of student procrastination before and after the transformative pedagogical experiment. There are significant differences between the students' procrastination levels before and after the experiment as well.
2. During the transformative pedagogical experiment (due to the career education program elaborated and implemented in practice), students gained experience of self-management, including self-evaluation, in relation to procrastination and achievement of their career goals.

3. Based on results of theoretical research, it can be said that the dropout risk in the experimental group of 1st year students was reduced along with the minimisation of their procrastination level.
4. The aim of the elaborated and experimentally approved career education programme has been achieved and the tasks have been accomplished.
5. The elaborated and experimentally approbated career education program is valid and can be further implemented for minimisation of student procrastination, it can contribute to career goals' achievement, and it can be used for the reduction of a dropout risk as there is a correlation between procrastination and dropout phenomena.

References

- Bardach, L., Lftenegger, M., Oczlon, S., Spiel, Ch., & Schober, B. (2019). Context-related problems and university students' dropout intentions-the bufferins effect of personal best goals. *European Journal of Psychology of Education*, 35, 477–493. DOI:10.1007/s10212-019-00433-9.
- Bäulke, L., Eckerlein, N., & Dresel, M. (2018). Interrelations between motivational regulation, procrastination and college dropout intentions. *Unterrichtswissenschaft*, 46(4), 461–479. DOI: 10.1007/s42010-018-0029-5.
- Brown, S.D., & Lent, R.W. (2017). Social cognitive career theory in a diverse world: Closing thoughts. *Journal of Career Assessment*, 25(1), 173–180. DOI: 10.1177/1069072716660061.
- Buliņa, R. (2011). Relations Between Adaptive and Maladaptive Perfectionism, Self-Efficacy, and Subjective Well-Being. *Psychology Research*, 4(10), 835–842.
- Carliner, S., Castonguay, C., Sheepy, E., Ribeiro, O., Sabri, H., Saylor, C., & Valle, A. (2015). The job of a performance consultant: a qualitative content analysis of job descriptions. *European Journal of Training and Development*, 39(6), 458–483. DOI: 10.1108/EJTD-01-2015-0006.
- Cheung, R.Y.M., & Ng, M.C.Y. (2019). Being in the moment later? Testing the inverse relation between mindfulness and procrastination. *Personality and Individual Differences*, 141, 123–126. DOI: 10.1016/j.paid.2018.12.015.
- Choi, J.N., & Moran, S.V. (2009). Why not procrastinate? Development and validation of a new active procrastination scale. *The Journal of Social Psychology*, 149, 195–212. DOI: 10.3200/SOCP.149.2.195-212.
- Dahling, J.J., & Librizzi, U.A. (2015). Integrating the theory of work adjustment and attachment theory to predict job turnover intentions. *Journal of Career Development*, 42(3), 215–228. DOI: 10.1177/0894845314545169.
- Eisenbeck, N., Carreno, D.F., & Ucles-Juarez, R. (2019). From psychological distress to academic procrastination: Exploring the role of psychological inflexibility. *Journal of Contextual Behavioral Science*, 19, 103–108. DOI: 10.1016/j.jcbs.2019.07.007.
- Ellis, A., & Knaus, W.J. (1977). *Overcoming Procrastination*. New York: Institute for Rational Living.
- Ferrari, J.R., Barnes, K.L., & Steel, P. (2009). Life regrets by avoidant and arousal procrastinators. *Journal of Individual Differences*, 30(3), 163–168. DOI: 10.1027/1614-0001.30.3.163.
- Ferrari, J.R., Diaz-Morales, J.F., O'Callaghan, J., Diaz, K., & Argumedo, D. (2007). Frequent behavioral delay tendencies by adults: International prevalence rates of chronic procrastination. *Journal of Cross-Cultural Psychology*, 38(4), 458–464. DOI: 10.1177/0022022107302314.
- Fernie, B.A., Kopar, U.Y., Fisher, P.L., & Spada, M.M. (2019). Further development and testing of the metacognitive model of procrastination: Self-reported academic performance. *Journal of Affective Disorders*, 240, 1–5. DOI: 10.1016/j.jad.2018.07.018.
- Ford, M. (2015). *Rise of the Robots: Technology and the Threat of a Jobless Future*. New York: Basic Books.
- Grau, J., & Minguillon, J. (2013). When procrastination leads to dropping out: analysing students at risk. *eLC Research Paper Series*, 6, 63–74. Retrieved November 13, 2019, from <https://www.raco.cat/index.php/eLearn/article/view/272013/359965>.
- Gubbels, J., van der Put, C.E., & Assink, M. (2019). Risk Factors for School Absenteeism and Dropout: A Meta-Analytic Review. *Journal of Youth and Adolescence*, 48, 1637–1667. DOI: 10.1007/s10964-019-01072-5.
- Gustavson, D.E., Miyake, A., Hewitt, J.K., & Friedman, N.P. (2014). Genetic relations among procrastination, impulsivity, and goal-management ability: Implications for the evolutionary origin of procrastination. *Psychological Science*, 25(6), 1178–1188. DOI: 10.1177/0956797614526260.
- Helyer, R., & Lee, D. (2014). The Role of Work Experience in the Future Employability of Higher Education Graduates. *Higher Education Quarterly*, 68(3), 348–372. DOI: 10.1111/hequ.12055.
- Klingsieck, K.B. (2013). Procrastination: When Good Things Don't Come to Those Who Wait. *European Psychologist*, 18(1), 24–34. DOI: 10.1027/1016-9040/a000138.

- Kljajic, K., & Gaudreau, P. (2018). Does it matter if students procrastinate more in some courses than in others? A multilevel perspective on procrastination and academic achievement. *Learning and Instruction*, 58, 193–200. DOI: 10.1016/j.learninstruc.2018.06.005.
- Lay, C. (1986). At last, my research article on procrastination. *Journal of Research in Personality*, 20, 474–495. DOI: 10.1016/0092-6566(86)90127-3.
- Luke, C., & Redekop, F. (2019). Gottfredson's Theory: Application of Circumscription and Compromise to Career Counseling. In G. Eliason, J. Patrick, J. Samide, & L. Lepore (Eds.), *Career development across the lifespan: Counseling for Community, Schools, Higher Education, and Beyond* (2nd Edition), A Volume in: Issues in Career Development (pp. 61–79). Harlotte, NC: Information Age Publishing, Inc.
- McCown, W.G., Johnson, J.L., & Petzel, T. (1989). Procrastination, a principal components analysis. *Personality and Individual Differences*, 10(2), 197–202.
- Neff, W. (2017). *Work and human behavior*. London: Routledge.
- Silkāne, V. (2018). *Prokrastinācijas, diskontēšanas un personības iezīmju saistība ar veselības uzvedību* (Relationship of procrastination, discounting, and personality traits to health behaviors). Doctoral Thesis. Riga: University of Latvia. (in Latvian).
- Silkāne, V., & Austers, I. (2017). Personības, diskontēšanas un uzdevuma raksturojuma loma prokrastinācijas un veselības prokrastinācijas skaidrošanā (Personality Traits, Time Discounting, and Task Characteristics in Explaining Procrastination and Health Procrastination). *Baltic Journal of Psychology*, 18 (1,2), 40–58. (in Latvian).
- Steel, P. (2007). The nature of procrastination: A meta-analytic and theoretical review of quintessential self-regulatory failure. *Psychological bulletin*, 133(1), 65–94. DOI: 10.1037/0033-2909.133.1.65.
- Steel, P. (2010). *The procrastination equation: How to stop putting things off and start getting stuff done*. Random House Canada. New York: Harper, c2011.
- Steel, P., & Klingsieck, K.B. (2016). Academic procrastination: Psychological antecedents revisited. *Australian Psychologist*, 51(1), 36–46. DOI: 10.1111/ap.12173.
- Taber, B.J., & Blankemeyer, M. (2015). Future work self and career adaptability in the prediction of proactive career behaviors. *Journal of Vocational Behavior*, 86, 20–27. DOI: 10.1016/j.jvb.2014.10.005.
- Tibbett, T.P., & Ferrari, J.R. (2015). The portrait of the procrastinator: Risk factors and results of an indecisive personality. *Personality and individual differences*, 82, 175–184.
- Wieland, L.M., Grunschel, C., Limberger, M.F., Schlotz, W., Ferrari, J.R., & Ebner-Priemer, U.W. (2018). The ecological momentary assessment of procrastination in daily life: Psychometric properties of a five-item short scale. *North American Journal of Psychology*, 20(2), 315–339.
- Wessel, J., Bradley, G., & Hood, M. (2019). Comparing effects of active and passive procrastination: A field study of behavioral delay. *Personality and Individual Differences*, 139, 152–157. DOI: 10.1016/j.paid.2018.11.020.
- Wistrich, A.J. (2008). Procrastination, deadlines, and statutes of limitation. *William & Mary Law Review*, 50(2), 607–667.

THEORETICAL AND LEGAL BASIS OF YOUNG PEOPLE'S MILITARY CAREER IN THE FIELD OF NATIONAL DEFENCE

*Sandra Kreija-Gaikste, Irena Katane

Latvia University of Life Sciences and Technologies, Latvia

*Corresponding author's email: sandra.kreija_gaikste@inbox.lv

Abstract

Research in many countries across the world, including Latvia, shows that youth participation in national defence is a topical issue. So far, scholarly research focusing on the promotion of youth participation in national defence and the provision of career support at school age and after finishing school is scarce. Therefore, the aim of the research was to establish the basis for young people's military career in national defence. Research results show that there is both theoretical and legal basis for young people to start a military career, already during school years. Based on the broad meaning of the concepts career and career development, young people's self-development, self-management and self-actualisation in various fields of human activity over one's lifetime emerge as topical issues. Such activities of various kinds may follow one another in succession or take place simultaneously, in parallel, in accordance with dual career theories. The beginning and development of young people's military career in Latvia can occur in the context of various activities already present and available in the near future: 1) participation in the Latvian Youth Guard as a type of non-formal education, 2) acquisition of National defence training at school in the context of formal education, 3) upon reaching legal age, voluntarily joining the Latvian National Guard, which is a component of the National Armed Forces of the Republic of Latvia.

Key words: formal and non-formal education, the Latvian Youth Guard, the Latvian National Guard, national defence, young people's military career.

Introduction

Several countries in the world have developed their own national defence concepts, which emphasise and highlight the role of youth participation in national defence, for example, France (Gougeon, 2017), Estonia (Estonian Ministry of Defence, 2011), the Russian Federation (Russian Federation's National ..., 2015), and others.

Scholars in many countries have published research on youth participation in national defence and related issues. For example, research carried out in the USA (Spoehr & Hand, 2018) shows that the armed forces may face issues concerning employment in the future (namely, the ability to recruit professional staff). There are several causes of this problem, for instance, limitations laid down in various legislative documents stipulating that only 29% of young people may be involved in professional national defence, among others. This poses a threat to continuity and generational renewal in the armed forces. Young people's motivation is another important factor to take into account.

Researchers outside Latvia have concluded in their studies that, in order to raise youth participation in national defence, it is necessary to raise awareness of the importance of civic education and provide a well thought-out civic education curriculum (Kalagbor & Harry, 2018).

Several documents regarding national defence have also been prepared in the Republic of Latvia, including the National Security Concept (LR Ministru kabinets, 2019), the Cyber Security Strategy of Latvia for 2019–2022 (LR Aizsardzības ministrija, 2019a), and On the introduction of national defence as a

subject and the development of Youth Guard in 2019–2027 (LR Aizsardzības ministrija, 2019b). These documents emphasise that 1) the aim of projects implemented as part of school and youth policy should be: the promotion of public engagement among young people; the exploration of historic events at parish, municipal, and national level; involvement in decision making so as to develop local patriotism and sense of belonging to the state; 2) it is necessary to educate young school-age people by building media competence and thus strengthening the psychological resilience of the younger members of society against threats and malicious actions in the information space in the long term; 3) National defence training should be introduced as a school subject to promote youth participation in national defence; the Youth Guard should continue its work, as its members could become the next generation to join the National Guard and enlist for professional service in the National Armed Forces of the Republic of Latvia.

Taking these considerations into account, it can be concluded that promoting youth preparedness for various types of participation in national defence is a request made by the state addressing the formal and non-formal education system in Latvia, and it has legal justification. At the same time, research conducted in Latvia (Vaine *et al.*, 2006) shows that, unfortunately, grade 8 students do not consider military career to be among the top 10 most promising fields of work. The opinions and attitudes of grade 11 students, when asked about the most promising fields of work, reflect a similar situation. Providing young people with career guidance in the military field can therefore be considered a vital issue to ensure that young people

can coordinate the three groups of factors determining their career choice (Aron, 2015; Katane *et al.*, 2017): 1) personal interests, needs, future goals and plans (what I want), 2) knowledge, skills, competences manifested as different abilities; experience (what I can), 3) the needs and demands of society, national priorities (what is needed).

So far, scholarly research focusing on the promotion of youth participation in national defence and the provision of career support at school age and after finishing school is scarce. Therefore, the aim of the research was to establish a basis for young people's military career in national defence.

Materials and Methods

In 2019, research on the promotion of young people's career in the field of defence was launched at the Latvia University of Life Sciences and Technologies. To conduct empirical research, a theoretical and legal basis is required. For this reason, the present paper introduces the results of theoretical research carried out by the authors, providing a rationale for young people's career in the military, beginning from school years and continuing until later, after finishing school. The following research methods were used: 1) review, analysis, and evaluation of scientific literature and various documents; 2) reflection on experience.

Results and Discussion

The theoretical basis of young people's career

Nowadays, in the 21st century, the concept of career is interpreted both in a narrow and broad sense. Multiple studies carried out in Latvia (Bloka, 2009; Gaile, 2019; Garleja & Kangro, 2015; Lemešonoka, 2014; Libkovska, 2011; Pudule, 2013) affirm both of these interpretations. Research shows that the reason for such variety of interpretations is the historical development of the concept of career and a gradual paradigm shift.

At first, career as a concept was generally associated with the chosen profession, a person's job and the employment process in a more narrow sense (namely, to what extent the choice of profession and professional development and growth can be considered successful), as well as work experience accumulated over time, and/or an individual's professional experience and the sequence of tasks to be completed in the respective position (Arnold, 1997; Arthur, Hall, & Lawrence, 1989; Arthur, Inkson, & Pringle, 1999; Lemešonoka, 2014).

Similarly, psychologist D. Super associated the notion career with professional development in his early research (Super, 1957). Based on his long-term research, together with fellow researchers and followers (D. Super, Savickas, & C. Super, 1996), he later established an important idea that career is a life-

long process that develops person's skills, abilities, and interests; the career development process accumulates new knowledge, establishes new characteristic features and attitudes, such as responsibility towards one's work, whose foundation, for a large part, lies in a person's system of values. These scientific findings significantly broadened the scope of the meaning of careers' idea.

Like D. Super and his followers, other scientists also came to the conclusion that career encompasses all-round personal development in main human activities, including social activities, in the context of achievement and successful self-actualisation over one's lifetime, deliberately satisfying one's personal needs, where as career development means the professional development of the person as a specialist and their character due to the interplay of these factors (Osipow & Fitzgerald, 1996).

The broad meaning of *career* as a notion is largely explained by etymology. The word *career* stems from the Latin word *carrus*, meaning *cart, carriage*. In Italian, *carriera* has the connotations of a run, the course of a person's life, one's field of work. In French, the word *carrière* can be defined as taking the lead in a particular field of activity, reaching popularity and fame (Хачатурян, 1999).

Several scientists established career theories in the 20th century, contributing to the multidimensional development of the concept. Career choice and development was studied and substantiated based on various perspectives with respect to 1) heredity and social learning (Krumboltz, 1994); 2) an individual's ability to achieve one's full potential in a varied environment, ensuring balance between one's interests, needs and goals and the interests, needs, development and functioning goals of the social environment (social group, for example, team at work, organisation, society at large), which ensures successful career development (Holland, 1985).

Nowadays, based on the views of career management theorists, scientists generally interpret the notion career in the broader sense, namely, as individual and professional development across a person's lifetime (Patton & McMahon, 2014).

In her research, I. Lemešonoka (Lemešonoka, 2014) underlines a comprehensive approach to the foundation, development, and study of one's career, which may serve as a conceptual basis for interpreting the notion career in its broader sense.

The semantic widening of the concept career can be also explained by the fact that historically career was studied within the context and from the perspective of different fields: psychology, sociology, political science, economics and management, and others.

For example, research carried out by G. Pudule (Pudule, 2013) explains the notion career from this

multidimensional, multidisciplinary perspective: 1) in economics, career is analysed as a reaction to the impact of market economy by analysing and studying response to short-term employment opportunities and accumulation of human capital in the longterm; 2) in management science, career is related to the development of human resource management; 3) in political science, career is analysed as the realisation of the interests of the European Union, focusing on an individual's need for power, welfare, prestige, and independence as an important manifestation of the European Union's interests within an institutional and political reality; 4) in sociology, career is analysed as the fulfilment of social roles, which overlaps with social psychology ideas, the difference being that sociology emphasises the mutual benefit gained by an individual and the society; career is also analysed in the context of social mobility. By far, the greatest influence on the development of career theories and career as a notion comes from research in psychology, where career is studied as 1) profession, in line with the view in traditional psychology that adult personality is characterised by stability; 2) self-actualisation, which represents the humanistic perspective and views career as individual growth having beneficial effect on the organisation where the individual is employed, as well as society as a whole; 3) part of an individual's life, supporting the idea that career is a multi-stage cyclical process which spans an entire lifetime and, like character development, is largely predictable, as it conforms with a human being's biological and social nature, that is, established regularities; 4) an individual's response to societal roles to be learned, including roles associated with professional activity; therefore, conditions specific to each profession should be studied, as they have a psychological impact on an individual's career development.

Several career development theories show career as a life-long multi-stage cyclical process. For example, S. Axelrad, E. Ginzberg, S.W. Ginsburg and J. Herma (Ginzberg *et al.*, 1951) provide a description of career development stages, beginning in childhood and young age, for instance: 1) stage one (until age 10–12) is characterised as fantasy through play; there are aspirations for the future, but these wishes are detached from reality; 2) stage two (12–16 years) is the stage of experimentation and temporary work, when interests, abilities and skills are determined; this is the age when one becomes aware of one's talents, likes and dislikes; 3) stage three (above age 17) is the stage when a realistic decision is made. This stage is divided in two levels. The first level involves making a decision on one's profession, based on one's experience – education, qualification, previous experimentation. Career development goals are defined and elaborated.

Notably, this framework can be used to exemplify career development theories, but it is more relevant to 20th century generations and only loosely applicable to the 21st century generations. The authors' experience shows that nowadays actual career development may start much sooner. Young school-age people may already be top-class athletes or winners of international music and dance competitions. Children and young people may appear in fashion shows, not unlike professional models. The Latvian Youth Guard is also such an example, where children and young people acquire real knowledge, skills, and competence in the military and have an opportunity to apply theoretical knowledge in practice.

Nowadays, career is explained and studied from various aspects, including the following (Bloka, 2009; Gaile, 2019; Garleja & Kangro, 2015): a person's professional experience during their lifetime; a person's employability; an experience of social interaction, which develops one's personal and social identity; leading a meaningful life, manifesting the self-evaluation of one's character competence, transforming one's competence capacity into intellectual capital; a self-regulation process where competence creates an added value in the form of social acceptance in the context of employing one's abilities; the effective use of a human's resources and inner potential in achieving life goals; dedicated efforts to build and employ one's competence over the entire lifetime; continual learning and development process; a person's social and professional advancement over the entire life.

Therefore, according to career theories of the 21st century, career is understood not only as professional growth, but also as logical development of one's character and the sequential change or mutual complementation of one's activities over the lifetime. Career is the dedicated, meaningful course of life of an individual; it is the sum of all roles, leisure activities, studies and work over the life of an individual.

Experience shows that nowadays one of the goals of education is to ensure career support to young people, including the provision of professional career pedagogues and career counsellors within the school education environment so as to promote the development of young people's careers, including professional self-determination.

Based on the broad meaning of the notion career in various career theories, as well as personal experience, the authors of the paper conclude that it is crucial for specialists involved in youth education to realise that it is not sufficient to view young people's career only from a future perspective, when appropriate education and professional skills will already have been acquired. It should also be examined from the viewpoint of the present, because youth career is established

and developed already at school: within formal and nonformal education, professional (such as arts, music, dance, sports, and other) education, as well as general comprehensive secondary education process. Professional education programmes are implemented simultaneously with the general basic education programme (LR Saeima, 1999). Experience shows that various types of programmes may be offered by the same education institution (for instance, general education institution (school) with classes providing additional vocational direction education, such as classes dedicated to music or sports education), or by different education institutions attended by children or youth (for example, general education elementary school and another school dedicated to music, the arts, or sports). General secondary education provides the following study directions for young people (LR Saeima, 1999):

- The general education direction, which is specified by the group of educational programmes without particularly emphasised subjects.
- The humanities and social direction specified by the group of educational programmes with particularly emphasised humanities subjects and social science subjects.
- The mathematics, natural sciences and technology direction determined by the group of educational programmes with particularly emphasised mathematics, natural sciences and technology subjects.
- The vocational direction determined by the group of educational programmes with a particularly emphasised vocational orientation (for example, the arts, music, business, sports, and others).

The diverse education acquired by young people already at school and later can be considered a significant part of their career, bringing new knowledge, skills, and competence to serve as the basis for their life as a whole, including professional development and activity.

Starting and developing of young people's military career in national defence area is already possible and will be so in the future: in formal education by studying the subject National defence training, and in non-formal education by participating in the Youth Guard, which offers various levels of education programmes. Such types of military education for young school-age people is a key component of career; for many young people, up on finishing school, the general experience acquired, as well as knowledge, skills, and competence in the field of national defence may serve as the basis for further development of military career in the Latvian National Guard or the National Armed Forces of the Republic of Latvia.

The historical and legal basis for the development of young people's military career in Latvia and future outlook for national defence

Considering the broad meaning of the notions career and career development, which imply that career encompasses the entirety of a person's life, including self-actualisation and personal and professional development by learning various social roles, youth participation in the Youth Guard as interest-related education or the National Guard as voluntary activity in the military context should also be considered a significant part of one's career if it becomes an important part of the person's life.

The Youth Law of the Republic of Latvia (LR Saeima, 2008) underlines that the purpose of the Law is to improve the quality of life of young people (persons from 13 to 25 years of age) by promoting their initiatives, work ethic and patriotism, participation in decision-making and social life. Therefore, support for youth is important in all activities they undertake in their life. In the context of career in its broader sense, the Youth Law highlights the vital role of support in young people's career development.

In addition to introducing new, competence-based curriculum, it is also necessary to review and bring into focus how children and young people develop and strengthen their sense of statehood and belonging to Latvia, learn to take responsibility for themselves, their family, community and the state, develop intellectual as well as physical ability, all during the process of acquiring education. In order to develop a society that is cohesive, resilient to external influence and able to mobilise in critical circumstances, each member of society needs to be aware of their role, duties and rights in emergency situations, they also need to be prepared to make decisions and take action in a very changeable environment. These competences are to be acquired and developed mainly in the family and at school, starting from early childhood, and also within extracurricular activities, including the Youth Guard, the largest children and youth movement in the military field in Latvia (LR Aizsardzības ministrija, 2019b). The goal of introducing the subject national defence in Latvian schools, namely, in formal education, and the Youth Guard, or non-formal education, is: to develop the skills and abilities necessary for life and national defence and promote civic consciousness and patriotism. Therefore, introducing National defence training as a compulsory study subject in formal education and studying the non-formal education curriculum provided by the Youth Guard, promotes young people's military career development by engaging them in various activities and acquiring the knowledge, skills and competence necessary for national defence.

Notably, since the 2018/2019 school year, the subject National defence training is already provided in several schools in Latvia which have voluntarily joined the approbation of the new curriculum and study process. Starting from the 2024/2025 school year, National defence training will be a mandatory subject in all schools in Latvia. It will be studied in grade 10 and 11 in general education secondary schools and in year 2 and 3 in vocational education institutions. According to forecasts from the Ministry of Defence of the Republic of Latvia, approximately 34 000 young people will study the subject in the first year when it becomes mandatory. The subject provides for individual approach with consideration of the worldview of students and their parents, including their religion and its respective values, beliefs, attitudes, actions, and behavioural norms. The curriculum will be taught at school and in camps offering practical exercises, therefore classroom attendance at national defence will be mandatory. However, schoolchildren engaged in distance and extramural education will have the opportunity to acquire new knowledge by only studying theoretical blocks, or modules, of the curriculum (Kuzmina, 2020).

Further developments are also planned for non-formal education in the Youth Guard, offering new Youth Guard education programmes. For example, there are plans to introduce Cyber Youth Guard classes in addition to level 2 Youth Guard interest-based education programme (for grade 7 and 8 students). Afterwards, these students can choose to enrol in a relevant vocational secondary education programme (for example, the Saldus Technical School already provides a programme for aspiring cyber security specialists) or a higher education programme in information technology with specialisation in cyber security (LR Aizsardzības ministrija, 2019b). As a result, new opportunities for young people's career development will become available.

The Youth Guard provides voluntary interest-related education (considered by the authors as a type of non-formal education) organised by the Ministry of Defence of the Republic of Latvia, which helps young people build civic consciousness and increase understanding of democratic society and national defence. The aim of the Youth Guard is to educate the youth about national defence; develop patriotism, civic consciousness, companionship, courage, physical ability and discipline; promote the National Armed Forces and military service among young people, as a result expanding recruitment opportunities of motivated professional soldiers (Ciganovs, 2019). The Military Service Law of the Republic of Latvia (LR Saeima, 2002) provides that: 1) children and youth from 10 up to 21 years of age may operate in the voluntary movement Youth Guard, whose

purpose is educating of youth in the field of national defence and the promotion of civic consciousness and patriotism; 2) the work of the Youth Guard, and also educating of youth in the field of national defence according to the interest-based education programme for youth guards is organised and implemented by the Cadet Force Centre or its authorised persons, 3) a model interest-based education programme for youth guards is approved by the Minister of Defence; 4) the Cadet Force Centre has the right to purchase weapons and ammunition for the purpose of carrying out the specified tasks; the procedures for storing and using them are stipulated by the Minister of Defence; 5) the uniform of a youth guard and an employee of the Cadet Force Centre and the identifying insignia of the Youth Guard, as well as the procedures for its use are determined by the Minister of Defence; the uniform of a youth guard and an employee of the Cadet Force Centre may be made of the fabric whose pattern is identical to that of the uniform of a soldier; 6) when a child joins the Youth Guard movement, the Cadet Force Centre enters into a contract on the participation of the child in the movement Youth Guard with their legal representative, but, if the young person has attained 18 years of age, the contract is concluded with the participant; 7) youth guards have the right to receive paid health care; the types, amount of paid health care services, conditions for receipt, and the procedures for payment are determined by the Cabinet of Ministers; 8) after reaching 18 years of age, a youth guard who complies with the requirements laid down in the Law and the conditions specified for the service into reserve may voluntarily complete a special interest-based education programme course for youth guards approved by the Minister of Defence; after successfully passing a final examination of this course, a youth guard takes an oath, is included in the National Armed Forces' reserve and awarded the rank of a private; if a youth guard has enlisted in professional service, they shall complete a basic training course of a soldier in accordance with the procedures stipulated by the Minister of Defence; 9) a reserve soldier may be removed from the military service record for various reasons, such as health conditions; one possible reason is voluntary joining the National Guard.

Career opportunities for young people in Latvia in the National Guard and Youth Guard emerged in the early 1990s. On 21 August 1991, immediately following the de facto restoration of independence of Latvia, the National Guard of the Republic of Latvia was established. Ever since its first battalions were formed, the National Guards who attended military training brought their children with them and, on their own initiative, engaged them in various National Guard activities. Children and youth groups spontaneously appeared along with the National Guard battalions,

and members of these groups were named the youth guards. During that time, Scout and 4-H organisations were restored on the initiative of separate individuals, and their programmes included patriotic and physical education for young people as well as productive free time activities, but not basic military skills. These skills were not provided by general education schools, either, and at that time there was no organisation that would educate school-age youth in the field of national defence. The Management of the National Guard took the coordination efforts and made a decision to merge and structure most of the children and youth groups established along with the respective National Guard battalions. On 25 November 1992, the Interim Regulations on the Youth Guard organisation of the Republic of Latvia were adopted at the National Guard Headquarters, and these regulations were approved by the Ministry of Education, Science and Culture of the Republic of Latvia on 30 November. The Regulations defined the three main objectives of the Youth Guard: to manage and organise the participation of young people in the Youth Guard; to provide the youth with the knowledge and skills necessary to prepare for military service; and to provide patriotic education for young people. The name Youth Guard, which until then had been used unofficially, also appeared in these Regulations for the first time (Ciganovs, 2019).

Military career options for young people are also laid down in The National Guard of the Republic of Latvia Law (LR Saeima, 2010). The purpose of this Law is to involve the citizens of Latvia in State defence. The Law also applies to young people who have reached legal age. It provides various support mechanisms to ensure motivated and voluntary participation in the National Guard within a cohesive national defence system. As the Law provides that the National Guard is a component of the National Armed Forces, in order to serve in the National Guard, the National Guards, including young people of legal age, have to give an oath and engage in career self-management to be able to combine studies in an education institution (for example, university) or work in a civil profession with military career duties in accordance with the Law. This problem provides the authors of this paper with opportunities for further study so as to provide theoretical basis for young people serving in the National Guard as a dual career.

References

- Arnold, J. (1997). *Managing Careers into the 21st Century*. London: Paul Chapman.
- Aron, I.S. (2017). Agency in Professional Self-Determination of Adolescents with Special Social Situations of Development. *Cultural-Historical Psychology*, 13(4), 64–72. DOI: 10.17759/chp.2017130407.
- Arthur, M.B., Hall, D.T., & Lawrence, B.S. (1989). *Generating new directions in career theory*. Cambridge: Cambridge University Press.
- Arthur, M.B., Inkson, K., & Pringle, J.K. (1999). *The new careers: Individual action and economic change*. Thousand Oaks, CA: Sage.

Conclusions

1. Nowadays, the importance of youth participation in national defence is a topical issue in Latvia and globally, as it can contribute to national independence and social sustainability in the territory of one's country. Increasingly more attention is paid to the importance of young people's military career development, starting already in school years and afterwards.
2. According to career theories of the 21st century, career is explained not only as professional growth, but also as logical character development and the sequential change or mutual complementation of one's activities across a person's lifetime. Career is the dedicated, meaningful course of life of an individual; it is the sum of all roles, leisure activities, studies and work over the life of an individual. Therefore, 20th century and especially 21st century career theories may serve as theoretical basis for young people's military career.
3. Based on the broad meaning of the concepts career and career development, young people's self-development, self-management and self-actualisation in various fields of human activity over one's lifetime emerge as topical issues. Such activities of various kinds may follow one another in succession or take place simultaneously, in parallel, in accordance with dual career theories.
4. The beginning and development of young people's military career in Latvia can occur in the context of various activities with legal basis: 1) participation in the Latvian Youth Guard as a type of non-formal education, 2) taking national defence classes at school in the context of formal education, 3) upon reaching legal age, voluntarily joining the Latvian National Guard, which is a component of the National Armed Forces of the Republic of Latvia.
5. In the near future, young school-age people will face new opportunities in military career development. The introduction of national defence as a subject in all schools in Latvia will affect the curriculum of the Youth Guard, including the Cyber Youth Guard, as well as school curriculum within the context of formal education.
6. To conclude, there is both theoretical and legal basis for young people in Latvia to start and develop a military career already during school years.

- Arthur, M.B., Khapova, S.N., & Wilderom, C.P.M. (2005). Career success in a boundaryless career world. *Journal of Organizational Behavior*, 26(2), 17–202. DOI: 10.1002/job.290.
- Bloka, R. (Red.). (2009). *Karjeras izglītība skolā*. Rīga: VIAA. (Career Education at School). (in Latvian).
- Ciganovs, J. (2019). Jaunsardze (The Latvian Youth Guard). *Nacionālā enciklopēdija*. Retrieved February 18, 2020, from <https://enciklopedija.lv/skirklis/31494-jaunsardze>. (in Latvian).
- Gaile, A. (2019). *Indivīda karjeras rīcību un individuālo vērtību mijiedarbība un ietekme uz subjektīvi veiksmīgu karjeru* (Interaction of personal career behaviours and values of an individual and effect thereof on subjective career success). Promocijas darbs. Rīga: RISEBA. (in Latvian).
- Garleja, R., & Kangro, I. (2015). Competence – karjeras iespēju garants. (Competence – the guarantor of career opportunities). In Proceedings of the International Scientific Conference Society. Integration. Education (pp. 133–144). Rezekne: RA. (in Latvian).
- Ginzberg, E., Ginsburg, S.W., Axelrad, S., & Herma, J. (1951). *Occupational choice: An approach to a general theory*. New York - London: Columbia University Press; Oxford University Press.
- Gougeon, C.F.-M. (Ed.). (2017). *Defence and National Security Strategic Review*. Paris: Ministry of the Armed Forces (Secretariat of the Committee).
- Holland, J.L. (1985). *Making vocational choices: A theory of vocational personalities and work environments*. Englewood Cliffs, NJ: Prentice Hall.
- Kalagbor, S.B., & Harry, D.M. (2018). Youth Empowerment and National Security in Nigeria: Issues and Prospects. *Global Journal of Political Science and Administration*, 6(3), 1–14.
- Katane, I., Katans, E., Korna, E., & Kristovska, I. (2017). Students' professional direction towards engineering professions at comprehensive secondary schools in the context of self-determination. In A Aboltins (Ed.), Proceedings of the 16th International Scientific Conference Engineering for Rural Development, Vol. 16, (pp. 811–818). Jelgava: LLU TF. DOI: 10.22616/ERDev2017.16.N165.
- Krumboltz, J.D. (1994). Improving Career Development Theory from a Social Learning Perspective. In M.L. Savickas, R.L. Lent (Eds.), *Convergence in Career Development Theories* (pp. 9–31). Palo Alto, CA: CPP Books.
- Kuzmina, I. (2020). Valsts aizsardzību apgūs gan skolās, gan nometnēs (National defence to be studied in schools as well as camps). *Ziņu portāls Latvijai*. Retrieved January 27, 2020, from <https://www.la.lv/valsts-aizsardzibu-apgus-gan-skolas-gan-nometnes?fbclid=IwAR0KRmc3v1Pkp0wFXmwFQk-mYjaUK96Dla5zHyIXjOkIL1KAWAiJP8cJphk>. (in Latvian).
- Lemešonoka, I. (2014). Professional Orientation and Career Education for Students. In Proceeding of the International Scientific Conference Society. Integration. Education, Vol. 1, (pp. 448–457). Rezekne: RTA.
- Libkovska, U. (2011). *Skolēnu profesionālo interešu pilnveides vadība karjeras izglītībā Latvijā* (Management of professional interests improvement of pupils in career education in Latvia). Promocijas darbs. Rīga: LU. (in Latvian).
- LR Aizsardzības ministrija. (2019a). *Latvijas kiberdrošības stratēģija 2019.–2022. gadam* (The Cyber Security Strategy of Latvia for 2019–2022). Informatīvais ziņojums. Rīga: LR Aizsardzības ministrija. (in Latvian).
- LR Aizsardzības ministrija. (2019b). *Par valsts aizsardzības mācības ieviešanu un Jaunsardzes attīstību 2019.–2027. gadā* (On the introduction of national defence as a subject and the development of the Youth Guard in 2019–2027). Informatīvais ziņojums. Rīga: LR Aizsardzības ministrija. (in Latvian).
- LR Ministru kabinets. (2019). Nacionālās drošības koncepcija. (National Security Concept). *Latvijas Vēstnesis*, 197. Retrieved March 6, 2020, from <https://likumi.lv/ta/id/309647-par-nacionalas-drosibas-koncepcijas-apstiprinasanu>. (in Latvian).
- Estonian Ministry of Defence. (2011). *National Defence Strategy of Estonia*. Tallin: Estonian Ministry of Defence.
- LR Saeima. (2008). Jaunatnes likums (The Youth Law). *Latvijas Vēstnesis*, 82 (28.05.2008). Retrieved December 12, 2019, from <https://likumi.lv/ta/id/175920-jaunatnes-likums>. (in Latvian).
- LR Saeima. (2010). Latvijas Republikas Zemessardzes likums (The National Guard of the Republic of Latvia Law). *Latvijas Vēstnesis*, 82. Retrieved February 18, 2020, from <https://likumi.lv/ta/id/210634-latvijas-republikas-zemessardzes-likums> (in Latvian).
- LR Saeima. (2002). Militārā dienesta likums (The Military Service Law). *Latvijas Vēstnesis*, 91. Retrieved February 18, 2020, from <https://likumi.lv/doc.php?id=63405>. (in Latvian).
- LR Saeima. (1999). Vispārējās izglītības likums (The General Education Law). *Latvijas Vēstnesis*, 213/215. Retrieved February 18, 2020, from <https://likumi.lv/doc.php?id=20243>. (in Latvian).
- Osipow, S.H., & Fitzgerald, L.F. (1996). Theories of career development. Boston: Allyn and Bacon.

- Patton, W., & McMahon, M. (2014). *Career Development and Systems Theory. Connecting theory and Practice*. Rotterdam: Sense Publishers. DOI: 10.1007/978-94-6209-635-6.
- Pudule, G. (2013). *Karjeras izglītības vadības pilnveide vispārīzglītojošās skolās Latvijā* (Improving the management of career education at the comprehensive schools of Latvia). Promocijas darbs. Rīga: LU. (in Latvian).
- Russian Federation's National Security Strategy. (2015). Moscow: the Kremlin.
- Spoehr, Th., & Handy, B. (2018). *The Looming National Security Crisis: Young Americans Unable to Serve in the Military: Report*. Washington: The Heritage Foundation. Retrieved March 6, 2020, from <http://report.heritage.org/bg3282>.
- Super, D. (1957). *The psychology of careers*. New York: Harper & Brothers.
- Super, D., Savickas, M., & Super, C. (1996). The life-span, life-space approach to careers. In D. Brown & L. Brooks (Eds.), *Career choice and development: Applying contemporary theories to practice* (pp.121–178). San Francisco: Jossey-Bass.
- Vaine, I., Kalēja, N., Čodere, A., & Trupavniece, A. (2006). *Pētījums par 8. un 11. klašu profesionālajiem nodomiem un priekšstatiem par profesijām* (Study on the professional aspirations and perception of professions in grade 8 and 11 students). Rīga: Profesionālās karjeras izvēles valsts aģentūra. (in Latvian).
- Хачатурян, Д.К. (Ред.). (1999). *Словарь иностранных слов* (Dictionary of Foreign Words). Москва: Омега. (in Russian).

DIALOGUE IS A SIGN OF CONSTRUCTIVENESS IN MEDIATION

***Viktorija Portere¹, Vladimirs Morevs²**

¹Latvia University of Life Sciences and Technologies, Latvia

²“PRIVUS” Ltd, Latvia

*Corresponding author's email: viktorija.portere@gmail.com

Abstract

Dialogue (discourse) is the main indication leading us to the conclusion that mediation is constructive. Discourse, the main form of dialogue, allows to achieve a positive result of mediation – an agreement between the participants of the conflict, as well as to learn dialogue communication skills. The aim of this study is to determine the types of dialogue used in mediation, the usage of recognized dialogue, and to find methods for assessing the dialogue (discourse) skills that need to be taught to the participants of the conflict, as well as future mediators and to evaluate the effectiveness of mediation. The research was conducted based on the theoretical methods of analysis of modern concept of dialogue and empirical testing methods (using questionnaires) of the participants of the conflicts and future mediators. Methods of mathematical statistics were used, when processing and analyzing the results of the questionnaires. As a result of this work, the types of dialogue used in mediation are identified, recommendations on the choice of components and barriers of dialogue to be considered by the mediator when training participants in the conflict and future mediators are made, as well as recommendations on assessment the effectiveness of mediation are offered.

Key words: types of dialogue, discourse, constructive mediation, construct.

Introduction

The dialogue is considered to be the key attribute of the constructive mediation. Mediation is aiming not only to solve the conflict but also to give the participants of the conflict the skills not to enter into a new conflict by teaching them the rules of dialogue, as the development model of society is based on the principle of harmony between the society and nature, cultural and civilization processes emplacing dialogical interaction (Yermolayeva, 2015). The field of applying the mediation is expanding due to continuously increasing importance of informal relationships and interpersonal connections in the life of society, growing numbers of legal regulations, governing the society, and their mutual inconsistency, as well as scientific and technological progress. There are more and more opportunities for various interpretations of conflict resolution methods.

Dialogue when translated literally from Greek is a speech (conversation) between two persons. The concept of dialogue developed from the existing everyday interpretation, when the dialogue is a written or spoken conversational exchange between two or more people, and a literary and theatrical form that depicts such an exchange, to the main form of communication between people who exchange not only words but signs that are intonations, in which these words are spoken, the actions of the dialogue subject, its silence and gestures.

It is teaching dialogue and using it as one of the main methods of counselling (Soika, 2015) in conducting mediation, changing the existing ‘construct’, that led to conflict, or creating a new ‘construct’ is the main characteristics of constructive mediation. The constructive approach is largely owing to the concept of ‘construct’. This concept gives an explanation and the name of this approach.

G. Kelly, the American psychologist, gave one of the most successful definitions of this concept: ‘Man looks at his world through transparent patterns or templates which he creates, and then attempts to fit over the realities of which the world is composed. The fit is not always very good. Yet without such patterns, the world appears to be such an undifferentiated homogeneity that man is unable to make any sense out of it... Let us give the name constructs to these patterns’ (Kelly, 1991).

Historically, the direction of constructivism, which recognized the primary role of dialogue, is called social constructivism: ‘This is a direction that recognizes the main role of discourse as a type of dialogue in the relationship between people in the world and their own ‘I’ construction, the need to abandon ideas about universal absolute truths, behavior standards, considering the psychological processes taking place in a person concerning the culture and history of specific communities, calling for voices and mutual enrichment of various discourses (languages and ways of interpreting the world), democratization and social transformation of people’s consciousness’ (Ulanovsky, 2009).

The discursive psychology, the founder of which was H.R. Harre, deserves our attention in social constructivism. In 1987, the work of J. Potter and M. Wetherell ‘Discourse and Social Psychology: Beyond Attitudes and Behavior’, Dialogical Self Theory of H.J.M. Hermans became fundamental in this direction. M. Bahtin, M. Buber, D. Bohm made a major contribution to the philosophical understanding of the concept of dialogue, an analysis of its historical development, an analysis of dialogue (discourse) development in communication in society – J. Habermas, the author of the Discourse Ethics or Communication Ethics.

The dialogue, its philosophy, components, and barriers in mediation, as well as types of mediation, are discussed also in the article Importance of Dialogue Nature in the Mediator's Competence (Portere & Briede, 2019).

Using existing approaches and interpretations of the concept of dialogue, the accumulated practical experience, competent performance (Adler & Pouliot, 2011), and the results of conducting numerous mediations, the aim of the study is to identify the types of dialogue used in mediation, to use one of the types of dialogue- recognizing dialogue to find methods for assessing the skills of dialogue (discourse) that need to be taught to the participants of the conflict, as well as future mediators and assess the effectiveness of mediation article will determine the types of dialogue used in the mediation.

In order to extract the types of dialogue used in mediation, there is a need to analyze history of this concept, the use and development of it by the above researchers.

Materials and Methods

One of the research methods used in this study is a theoretical analysis of the dialogue description given in the works of the most important authors from the point of this study, first of all above mentioned constructivists, as well as analysis of existing approaches and interpretations of the concept of dialogue. Also, an empirical method such as questioning of the parties to the conflict and future mediators, as well as methods of mathematical statistics for processing the results of the survey have been used.

The types of dialogs in mediation

The history of this concept of dialogue was analyzed by M. Bahtin, a famous ideologist of dialogue, whose work was accompanied by the statement 'to be means to communicate dialogically' (Bahtin, 1979).

Researching the 'Socratic Dialogue' M. Bahtin wrote: 'Socratic Dialogue is a special and widespread genre in its time. At the base of the genre lies the Socratic notion of the dialogic nature of truth, and the dialogic nature of human thinking about truth... Truth is not born nor it is to be found inside the head of a person, it is born between people collectively searching for truth, in the process of their dialogic interaction. Socrates called himself a 'pander': he brought people together and made them collide in a quarrel, and as a result, truth was born' (Bahtin, 1979).

M. Bahtin emphasized the following methods of Socratic dialogue:

- o syncrisis – a comparison of different points of view on a particular subject;
- o anacrisis – ways to provoke the words of the interlocutor, make him express his opinion to the end;

- o diatribe – a rhetorical genre of dialogue, usually constructed in the form of conversation with absent interlocutor;
- o soliloquium – dialogical attitude to oneself, that is, a conversation with oneself.

For this purpose, the dialogue plot situation can be used.

Next, let us consider the main ideas that can also be taken from the previously named authors to achieve the desired goal.

It is important for this research to discuss the Dialogical Self Theory by H.J.M. Hermans. The main idea of this theory is based on the understanding of the human self as a dynamic set of 'I-positions'.

'By I-position one understands various roles, self-expression, it is also others in me – images of surrounding people, voices and characters typical for this or another culture. Position is also animals, objects, cultural symbols, nature, God or nature. Position is a relatively autonomous subject which possesses its own voice, world-view, ability to respond' (Hermans, 2012).

That is, the human 'I' represents a variety of positions that are in the process of change, interaction and communication.

H.J.M. Hermans offers to set apart a) internal part of the self; b) external part of the self c) society – 'real others', people surrounding the human (Hermans, 2012).

H.J.M. Hermans offers to examine the dialogue in opposition to the monologue and includes in it:

- o 'listening to each opinion;
- o granting of space to everybody for expressing his/her experience and opinion;
- o being interested in discovering of a possible non-understanding and wish to correct it;
- o readiness to learn from each other based on mutual exchange' (Hermans, 2012).

H.R. Harre, one of the first discursive psychology theoreticians, notes that 'everyday language is the most important source of knowledge of the human psyche because the study of a person should take into account the inclusion of personality in a cultural and sociological context, not limited to the neural process description.' (Van Langenhove, 2010).

J. Potter and M. Wetherell formed the main points of discursive psychology in the book 'Discourse and Social Psychology: Beyond Attitudes and Behaviour':

- o 'the principle of constructivity: discourse is constructed with words and constructs the social world itself.
- o the principle of intentionality: discourse is focused on actions and social practices.
- o the principle of situationality: discursive actions are derived from communicative, rhetorical, and institutional situations' (Potter & Wetherell, 1987).

This way, based on these provisions, psychological constructs are created, adjusted and used in the process of social contacts, and therefore in the dialogue process.

The subject continuously creates its identity in society that is why it cannot be forced to think separately from it.

It is argued that mental processes and discourse are of a communicative nature, and cognition is a set of symbolic language tools.

M. Buber gave the following definition of dialogue: 'I know three types of dialogue: genuine dialogue – no matter whether spoken or silent – where each of the participants really has in mind the other or others in their present and particular being and turns to them with the intention of establishing a living mutual relation between himself and them; technical dialogue, which is prompted solely by the need of objective understanding; disguised as dialogue monolog, in which two or several men, meeting in space, speak each with himself in strangely tortuous and circuitous ways and yet imagine they have escaped the torment of being thrown back on their own resources' (Buber, 1995).

J. Habermas distinguishes between 'implicit and explicit options for providing a claim of a vocal act to significance. The first occurs at the level of direct, 'naïve' communication. If consensus cannot be reached at this level, then as an alternative to stopping communication or using the language instrumentally (to influence partners), discourse is a way to test a conflicting claim to significance by arguing in a dialogue as a process aimed at achieving universally valid consensus' (Habermas, 1981).

D. Bohm gave the following definition to the dialogue: 'Dialogue can be considered as a free flow of meaning between people in communication, in the sense of a stream that flows between banks' (David Bohm Society, 2019). D. Bohm defined the following rules for conducting a dialogue: in the dialogue group we are not going to decide what to do about anything. There must be freedom to speak or not speak. Assumptions and judgments should be avoided. Dialogue should proceed as honestly and transparently as possible. Those who participate in reflection are based on the thoughts of another. He also stressed the importance of facilitator's participation in dialogue group that oversees the implementation of the above rules (Bohm, 2004).

Dialogue in the mediation is a tool for regaining the self-esteem of the persons involved in this process, instrument of inquiring into the situation, promotion of mutual respect and understanding and democracy (Portere & Briede, 2019) and means of finding the solution. V. Portere and B. Briede highlighted the components and barriers to the dialogue that make

up the dialogue of the participants and the mediation (Portere & Briede, 2019).

Dialogue in the mediation process provides the following functions and stages:

- o ensuring a positive atmosphere for mediation and relations between the participants in the conflict;
- o obtaining information about the conflict, participants in the conflict, intentions, interests, needs and wishes of the participants;
- o determining the level of conflict participants' dialogue possession and possible dialogue barriers, the unambiguous perception of indications;
- o discussing possible options for achieving the participants' interests and solving the conflict;
- o reaching final agreement between the participants in the conflict.

Recognizing dialogue function by questionnaire

While reviewing one of the dialogue types recognizing dialogue, the questionnaire method is used. Questions are composed using on the principles of Socrates's method (Clark & Egan, 2015). The questionnaires provide verification of their own completion accuracy. The questionnaires composition includes questions that characterize the participants and the conflict, initial, guiding and final questions that help the mediator to mediate. Questionnaires are filled out by the participants in the conflict, participating in mediation or persons trained in mediation.

During the mediation with the help of questionnaires, it is possible to gather necessary information:

- o to get acquainted with the conflict, participants in the conflict, which is used for further mediation;
- o to define the degree of unambiguity of perception of indications by the participants in the conflict;
- o to define the level of dialogue possession by the participants in the conflict;
- o to characterize the psychological constructs of the participants in the conflict that impede consensus achievement, the true interests and needs of the participants in the conflict;
- o to define and establish strengths and weaknesses of different options for solving the conflict.

For the purposes of this article, the information collection and processing required to define the level of dialogue possession by the participants in the conflict or persons trained in mediation is considered.

While composing the questionnaires, the components and barriers of dialogue highlighted in the article 'Importance of Dialogue Nature in the Mediator's Competence' (Portere & Briede, 2019) were used.

To ensure the validity of the results, the composition of the questionnaires was checked for consistency by calculating Cronbachs Alpha coefficient, taking 0.7 as the minimal acceptable value. To achieve an acceptable value of the coefficient, some components of questionnaires have been modified.

The respondents have the possibility to assess the usage of dialogue components and presence of psychological barriers by answering each question of the questionnaire: 'no', 'partly', 'yes'. For processing of questionnaires each answer has its own numerical designation (points): 'no' – 1, 'partly' – 2, 'yes' – 3.

The verification of the reliability and conscientiousness of filling out the questionnaire was ensured by including control questions, which shouldn't have different or opposite answers, and setting the appropriate rules for respondents.

The questionnaires were processed using mathematical methods and the SPSS system (George & Mallery, 2019) the internal consistency of the questions and emerging statistical patters (correlation) of the answers are analyzed.

As a result of processing the questionnaires, statistical coefficients that determine the internal consistency of indicators, descriptive statistics indicators, the normality of the distribution of statistical observations, the correlation degree of various indicators of the questionnaire were identified. The revealed patterns were used in the mediation process.

Total surveyed:

- o persons wishing to learn mediation (future mediators) for subsequent use in personal and professional activities – 26 people (there are 5 men and 21 women, aged 25–67 years, with secondary specialized and higher education).
- o participants in the conflict during the mediation process of five mediations for the settlement of family relations in terms of joint communication in the family – 16 people (8 couples, of which 8 are men and 8 women, aged 35–50 years, with secondary specialized and higher education).

Results and Discussion

Let us identify the following types of dialogue in constructive mediation based on the analysis of mediation functions and stages, existing approaches and definitions of the concept 'dialogue':

- o Dialogue, aimed at creating an atmosphere of cooperation in the mediation process;
- o Recognizing dialogue, during which the mediator and the participants find out conflict data characteristics, come to a uniform understanding of its essence and legal grounds; it is the recognizing dialogue that can be conducted on the form of questionnaires;

- o Discursive dialogue (discourse), which is the main tool of reaching the agreement by the participants in the conflict. The mediator directs the discourse and, if it is necessary, sets its program;
- o Crisis intervention dialogue, aimed at recognizing and analyzing emotions;
- o Transformative dialogue, aimed at clarifying and drawing together the points of view, opinions and worldview of the participants in the conflict;
- o Provocative dialogue in which the opinions and thoughts of one or both participants in the conflict are provoked to gain confidence in the stability and reliability of their thoughts and judgments.

Dialogue, aimed at creating an atmosphere of cooperation in the mediation process, is conducted by the mediator with the participants in the conflict to create a trusting atmosphere in the mediation process (affiliate communication), explain mediation rules, and achieve consensus between the participants on cooperation.

During the recognizing dialogue experience and methods of hermeneutics, theory of interpretation and understanding of texts, are used.

Discursive dialogue involves the exchange of evidence (arguments) to achieve the mediation aim. This type of dialogue is necessary to solve complicated conflicts.

During the transformative dialogue the principles laid down by D. Bohm are used when the participants try to achieve a common understanding of themselves, the partner and the situation, taking into account completely and equally the point of view of each participant.

During crisis intervention, dialogue is conducted to identify and discuss the feelings and emotions of the participants in the conflict, their causes, as well as possible consequences. The essence of such a dialogue is to show that the participants in the conflict are equally heard, accepted, understood by the mediator. It contributes to mutual acceptance and respect from the participants in the conflict.

Provocative dialogue, in contrast to crisis intervention, is aimed at identifying doubts and reasoning about the consistency of opinion about a conflict situation, it's a possible solution or personality and the character of the participant in the conflict, personal worldview and oneself.

Recognizing dialogue can be handled using the method of questionnaire. In this research, a questionnaire to determine the level of dialogue skills of conflict participants and persons trained in mediation has been conducted.

Used questionnaires details correspond to the dialogue components identified in the article

‘Importance of Dialogue Nature in the Mediator’s Competence’ (Portere & Briede, 2019). The selection of components included in the questionnaires was carried out by checking their internal consistency using trial questionnaires and calculating the statistical coefficient Cronbaphs Alpha for completed answers. As a result, the following composition of components have been obtained:

- o Evaluate the partner as a unique personality;
- o Respecting of positions/ views;
- o Emphatic understanding;
- o Clear expression of information;
- o Tolerance;
- o Recognition of the partner’s emotions;
- o Searching for the sense of conversation;
- o Responsibility for one’s words uttered;
- o Mutual equality of rights;
- o Listening and hearing;
- o Logic of the conversation;
- o Readiness to obtain additional knowledge;
- o Active listening;
- o Readiness to change one’s viewpoint, opinions, assumptions;
- o Eye contact;
- o Openness;
- o Seriousness towards the dialogue process;
- o Desire to find the truth;
- o Desire to have the dialogue process;
- o Seriousness towards the dialogue’s partner and barriers hindering the dialogue;
- o Lack of interest about the dialogue’s theme;
- o Lack of motivation to implement dialogue;
- o Lack of time for dialogue;
- o Fear of the dialogue process and/or its outcome;
- o Fear of new information/ new knowledge;
- o Fear that one’s knowledge for conversation will be insufficient;
- o Lack of respect towards the partner;
- o Reluctance (fear) to change one’s opinion, attitude, position;

- o Lack of empathy towards the partner;
- o Non-conformity of values and/or intellect of the partners;
- o Incomprehension of verbal and nonverbal communication of the partner;
- o Phobias;
- o Inability to concentrate for the dialogue process (internal circumstances);
- o Various external disturbances/ circumstances.

Filling out of questionnaires was controlled by including in their composition control questions the answer to which must comply with certain rules. The answer to the question ‘I evaluate the partner as a unique personality’ must have at least 2 points, if answers to the questions ‘Respecting of positions/ opinions’, ‘Tolerance’, ‘Mutual equality of rights’ have 2 or 3 points. If these rules are not complied with, the mediator carries out additional preparation of the respondent how to correctly fill out questionnaires and performs a repeated filling of them.

While processing questionnaires filled out by people studying mediation, the decision on topics to be additionally explained in more detail as well as selection of appropriate training methodology can be made. The basis of this decision is the deviation of the average number of points obtained when answering the questions of the questionnaire: lower than the average in the case of questionnaires on the dialogue components and higher than the average in the case of questionnaires on dialogue barriers.

The results obtained while processing questionnaires filled out by people studying mediation, allows to conclude that the answers to the questions given in Table 1 are in correlation with each other. The degree of correlation is indicated in the table using the Spearman coefficient.

The Cronbaphs Alpha coefficient obtained during the processing of these questionnaires is 0.700 (for dialogue components) and 0.760 (for dialogue barriers), as well as a fairly large number of processed

Table 1

Correlated Questionnaire Questions

Questions about components and dialogue barriers from the questionnaires	Questions with correlating relation	Spearman correlation coefficient
Position / respect of beliefs	Mutual equality	0.600
Active listening	Listening and hearing	0.588
Seriousness in dialogue processes	Seriousness towards the dialogue partner	0.843
Lack of interest in dialogue	Lack of motivation for dialogue	0.608
Fear of new information	Phobias	0.778
Fear of lack of knowledge for a conversation	Phobias	0.601
Partner value and/or intellectual incompatibility	Incomprehension of partner communication	0.673
Inability to concentrate on a dialogue process	Different external disturbances/ circumstances	0.605

observations and practical experience of conducted mediations (including family mediations) allow using this regularity in the work of a mediator with participants of the conflict.

It can be hypothesized that an increase in the number of observations, obtained from people not involved in a conflict, will allow to enhance this list and, accordingly, help the mediator to conduct dialogue training during the mediation process.

Mediation participants fill in the questionnaire at the beginning and in the end of a mediation process. While processing the questionnaire, at the beginning of a mediation process the mediator pays attention to the opposite answers (point 1 and point 3) to questions that are statistically correlated based on the Table 1, as well as to the case when The Cronbaphs Alpha coefficient obtained by processing the results of the initial survey was less than 0. Wherein each mediation participant is interpreted as a variable. As a result, the mediator determines which dialogue components need to be changed, which dialogue barriers need to be removed and, accordingly, selects methods for teaching dialogue.

Mediation practice has shown that if a preliminary questionnaire is conducted among conflict participants, certain answers can lead them to awareness of possibility to eliminate contradictions that caused the conflict and, consequently, to resolve the conflict without full process of mediation.

Accordingly in questionnaires used in this research, the answer 'no' to the questions 'Readiness to change one's viewpoint, opinions, assumptions' or 'yes' to the questions 'Lack of interest about the dialogue's theme', 'Lack of motivation to implement dialogue', 'Fear of the dialogue process and/or its outcome', 'Fear of new information/ new knowledge', 'Fear that one's knowledge for conversation will be insufficient' can be used for the above purpose.

To assess the mediation success after it has been carried out, the questionnaires are filled in. Comparison of the questionnaires completed during and after finishing the mediation process led to the conclusion that the success of mediation is also characterized by a certain degree of shift in the number of series obtained on the basis of an increase in the number of answers 'yes' (point 3) from the normal distribution while processing questionnaires with dialogue components and increasing the number of answers 'no' (point 1) while processing questionnaires with dialogue barriers (Table 1). The Cronbaphs Alpha coefficient obtained

by processing these profiles is 0.849 (for dialogue components) and 0.709 (for dialogue barriers).

Conclusions

As a result of the work, the types of dialogue used in mediation and characterizing a constructive approach to it are highlighted:

- o Dialogue aimed at creating an atmosphere of cooperation in the mediation process;
- o Recognizing dialogue;
- o Discursive dialogue (discourse);
- o Crisis intervention dialogue;
- o Transformative dialogue;
- o Provocative dialogue.

Questionnaires for collecting information about dialogue components and barriers by participants of mediation and future mediators have been developed. The components and barriers of dialogue among mediation participants have been identified and evaluated.

The procedure for filling out and verifying the validity of questionnaires has been worked out.

The consistency of questions in the questionnaires is determined by calculating the Cronbapha Alpha coefficients. Values obtained from the questionnaires completed by individuals who are trained in mediation are 0.700 (for dialogue components) and 0.760 (for dialogue barriers); and from the ones completed by mediation participants are 0.849 (for dialogue components) and 0.709 (for dialogue barriers). This shows as sufficient consistency and reliability of the processed data.

Statistically processing the results of the questionnaires, completed by individuals who are being trained in mediation, the criteria of elaboration of their educational program has been determined and correlations between several questions in the questionnaires defined with the aim to be used for conflict parties during the mediation process. The conclusion is drawn about the necessity to further refine the revealed patterns based on the results of post-mediation process questioning as well as questionnaires completed by future mediators in the process of their training.

It is important to highlight the revealed possibility to bring the conflict participants to resolving the conflict based on questionnaire process without full process of mediation.

Questionnaires filled in after the successful completion of mediation, identified the evidence of the success of the mediation process.

References

- Adler, E., & Pouliot, V. (2011). International Practices. *International Theory*, 3(1), 1–36. DOI: 10.1017/S175297191000031X.
- Bahtin, M. (1979). *Проблемы поэтики Достоевского (Problems of Dostoevsky's Poetics)*. Moscow: Sovetskaja Rosija. (in Russian).

- Bohm, D. (2004). *On Dialogue*. Psychology Press. Routledge Classics. Retrieved March 3, 2020, from https://books.google.lv/books?id=MGGF_oF_aY0C&printsec=frontcover&source=gbs_ge_summary_r&cad=0#v=onepage&q&f=false.
- Buber, M. (1995). *Сборник 'Два образа веры. Диалог' (Collection 'Two Images of Faith. Dialogue')*. Moscow: Respublika. (in Russian).
- Clark, G.I., & Egan, S.J. (2015). The Socratic Method in Cognitive Behavioural Therapy: A Narrative Review. *Cognitive Therapy and Research*, 39(6), 863–879. DOI: 10.1007/s10608-015-9707-3.
- David Bohm Society. (2019). Bohm Dialogue. Retrieved March 3, 2020, from <https://bohmdialogue.org/#bohmdialogue>.
- George, D., & Mallery, P. (2019). *IBM SPSS Statistics 25 Step by Step: A Simple Guide and Reference*. Taylor & Francis. DOI: 10.4324/9781351033909.
- Habermas, J. (1981). *Theorie des kommunikativen Handelns (Theory of Communicative Action)*. Frankfurt am Main. (in German)
- Hermans, H.J.M. (2012). *History, Main Tenets and Core Concepts of 'Dialogical Self' Theory // Handbook of Dialogical Self theory* / Cambridge: Cambridge university press.
- Kelly, G. (1991). *The Psychology of Personal Constructs*. Routledge in association with the Centre for Personal Construct Psychology.
- Portere, V., & Briede, B. (2019). Importance of Dialogue Nature in the Mediator's Competence. *ENVIRONMENT. EDUCATION. PERSONALITY*, 12, 146–151. DOI: 10.22616/REEP.2019.018.
- Potter, J., & Wetherell, M. (1987). *Discourse and Social Psychology: Beyond Attitudes and Behavior*. Retrieved March 3, 2020, from https://scholar.google.co.uk/scholar?as_sauthors=J+Potter&as_q=Discourse+and+Social+Psychology%3A+Beyond+Attitudes+and+Behaviour&as_occt=title.
- Soika, I. (2015). *Entity of Dialogue in Career Guidance of Secondary Vocational Schools*. *ENVIRONMENT. EDUCATION. PERSONALITY ISSN*. Retrieved March 3, 2020, from <http://lufb.llu.lv/conference/REEP/2015/Latvia-Univ-Agricult-REEP-2015proceedings-338-346.pdf>.
- Ulanovsky, A.M. (2009). Конструктивизм, радикальный конструктивизм, социальный конструкционизм: мир как интерпретация (Constructivism, Radical Constructivism, Social Constructionism: the World as an Interpretation). *Question of Psychology*, 2, 35–45. Retrieved March 3, 2020, from [http://www.psy.msu.ru/people/ulanovsky/2009/Ulanovsky Constructivism, radical ..ctivism, social constructionism.pdf](http://www.psy.msu.ru/people/ulanovsky/2009/Ulanovsky%20Constructivism,%20radical%20..ctivism,%20social%20constructionism.pdf). (in Russian).
- Van Langenhove, L. (2010). *People and Societies: Rom Harré and Designing the Social sSciences*. *People and Societies: Rom Harré and Designing the Social Sciences*. Routledge. DOI: 10.4324/9780203860885.
- Yermolayeva, Y.V. (2015). The Main Characteristics of Dialogic Interaction (Defining the Actual Tasks of Pedagogic Dialog). *The Education and Science Journal*, 1(7), 18. DOI: 10.17853/1994-5639-2012-7-18-34.

Annual 26th International
Scientific Conference

Research for Rural Development

2020



Volume 35

ONLINE ISSN 2255-923X
ISSN 1691-4031