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RURAL DEVELOPMENT 2021**

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FOREWORD

The Latvia University of Life Sciences and Technologies and Organizing Committee of Annual 27th International Scientific Conference '*Research for Rural Development 2021*' tried to continue a tradition of bringing together researchers, academic and professionals in Jelgava, from 12 to 14 May, 2021 from all over the world. But, unfortunately, this year again the rules were set by the Covid -19 virus pandemic.

We did start new tradition from 2020, account from 1st until the 27th conference and totally are 36 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 2021*' and look forward to the 28th conference in 2022.

Ausma Markevica
Chairperson
Annual 27th International Scientific Conference
'*Research for Rural Development 2021*'

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ASSESSMENT OF PERENNIAL RYEGRASS (*LOLIUM PERENNE* L.) GENOTYPES UNDER LATVIA AGRO-ECOLOGICAL CONDITIONS



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Abstract

Within the frame of the Nordic/Baltic public-private partnership 'PPP for pre-breeding in perennial ryegrass' various activities were performed, including assessment of *L. perenne* (Lp) genotypes under agro-ecological conditions of Latvia. This article summarizes the data obtained in two harvest years for 19 intermediate tetraploid (4x) Lp genotypes. In order to compare the results obtained in ryegrass with performance of grass interspecies hybrids (F1), which become especially relevant in the recent years, two varieties, developed in Latvia – *Lolium* × *boucheanum* Kunth. 'Saikava' and × *Festulolium* 'Vizule' were included in the experiment. Various scores were performed, including evaluation of regrowth, intensity of culm development, sward cover, crown rust (*Puccinia coronata*) susceptibility, etc. The dry matter yield (DMY) and fodder quality were also determined. It can be concluded that the genotypes showed relatively good results in the first two harvest years. Wintering conditions were favourable. Despite the intensified drought and heat in the 1st ley year, relatively high DMY, which ranged from 9.30 to 12.15 t ha⁻¹, for Lp were harvested in three cuts. In the 2nd ley year, under more favourable humidity conditions, Lp in four cuts provided similar DMY, which ranged from 8.81 to 11.50 t ha⁻¹. If we compare the average DMY of Lp and F1 genotypes, it can be concluded that in the first two harvest years no significant differences were found, the average DMY was 10.30 and 10.64 t ha⁻¹, respectively. No significant differences were found between Lp and F1 in terms of forage quality.

Key words: festulolium, variety, dry matter yield, phenological assessment, fodder quality.

Introduction

Perennial ryegrass (*Lolium perenne* L.) is a very important species in providing a feed base for ruminants. It is high-yielding with excellent forage quality under frequent cutting regime; therefore, perennial ryegrass is the most important forage grass species in many regions with mild, humid climate. As the temperature is rising, it is expected that in near future the growing area of perennial ryegrass will expand to the north. In the Nordic-Baltic region perennial ryegrass becomes increasingly important, especially in view of the prospective climate changes. Currently, the cultivation of perennial ryegrass in Northern Europe is a challenge due to unstable wintering circumstances with black-frost in winter and sharp temperature fluctuations in spring. Heat and drought periods in summer are also becoming more present and pronounced. It is of great importance to contribute to increasing the diversity of ryegrass genetic material in order to improve winter hardiness, persistence and stress tolerance of perennial ryegrass. For this purpose the researchers and breeders in the Nordic and Baltic countries joined their forces in collaboration within the long-term Public-Private Partnership (PPP) project on pre-breeding of perennial ryegrass (Rognli *et al.*, 2019; Rancane *et al.*, 2021). The PPP project aims to assess available genetic resources and develop new germplasm which can be used to develop resilient cultivars highly adaptable in new conditions. Current perennial ryegrass germplasm is probably restricted since the species is not native to the northern and continental regions (Rognli *et al.*, 2013). The best strategy for future breeding could be

hybridization of germplasm developed in northern countries with more exotic materials that allows to develop new varieties combining high yield potential, good winter survival and superior disease resistance (Helgadottir *et al.*, 2018).

For increasing the genetic diversity of perennial ryegrass and improving its properties tetraploid forms are created. During the studies of the effect of variety ploidy and heading date on milk production and herbage intake of dairy cows it was found that later heading varieties had increased dry matter intakes (DMI) and milk production over intermediate heading varieties, but ploidy did not have a significant effect. Tetraploid swards had lower post-grazing sward heights than diploid swards but milk production did not differ significantly. Tetraploids exhibited significantly better graze-out performance than diploids. The proportion of tetraploid varieties in intensively grazed swards should be optimized. Breeding for improvements in grazing efficiency is possible which is confirmed by genetic variation between varieties within each ploidy (O'Donovan & Delaby, 2005; McClearn *et al.*, 2019; Tubritt *et al.*, 2020). Increasing genome size during selective breeding process by whole genome duplication, changes the productivity and stress tolerance of new varieties. Lee *et al.* (2019) found that tetraploids exhibited a greater biomass under severe drought, whereas diploids had a greater biomass under the current rainfall and likely drought scenarios. Local climate forecasts will need to be taken into account when selecting new varieties, allowing for variable future reductions in precipitation.

However, some grass breeders (Berzins *et al.*, 2015, 2018; Nekrošas & Kemešytė, 2007; Ostrem, Volden, & Larsen, 2013) believe that under the climatic conditions of Northern Europe more promising is the development of interspecific (*Festuca* × *Lolium*) grass hybrids that allows to combine the best properties of both species in one variety. Forage nutritive value and the regrowth capacity of ×*Festulolium* could make it as promising species for high-latitude regions (Ostrem, Novoa-Garrido, & Larsen, 2013). Previous studies have shown that many varieties of ×*Festulolium* have improved winter-hardiness and persistence in comparison with *L. perenne* (Lemežiene *et al.*, 2004; Gutmane & Adamovics, 2008; Ghesquiere, Humphreys, & Zwierzykowski, 2010; Berzins *et al.*, 2015). In Sweden, they found that the decline in dry matter yield at first harvest over three years was largest in perennial ryegrass, it was significantly less in loloid festulolium, while the smallest reduction in yield was found for festucoid festulolium (Halling, 2012). Research in this area is still lacking; therefore, in the experiment tetraploid (4x) perennial ryegrass varieties and accessions from different locations, and two local varieties of interspecific hybrids were included. The aim of the study was to compare and find the most productive and persistent perennial ryegrass varieties and accessions under Latvia agro-climatic conditions, and evaluate their performance in comparison with festulolium.

Materials and Methods

The field trials were conducted at the Research Institute of Agronomy (56°37 N, 25°07 E) of Latvia University of Life Sciences and Technologies. The experiment included 19 intermediate tetraploid (4x) perennial ryegrass (Lp) varieties and genebank accessions (hereinafter genotypes) and two grass interspecific hybrid (F1) varieties developed in Latvia – the hybrid ryegrass (*Lolium boucheanum* Kunth.) ‘Saikava’ and festulolium (×*Festulolium*)

‘Vizule’. Genotypes were randomized in two replicates. The size of the plot for each genotype in one replicate was 10 m². The trial was established in June of 2018 in Eutric Retisol (WRB, 2014), granulometric composition was loamy sand, with pH KCl 5.7, organic matter 22 g kg⁻¹, plant available phosphorus (P₂O₅) 85 mg kg⁻¹ and potassium (K₂O) 95 mg kg⁻¹. In the sowing year before establishment of experiment a fertiliser with 20 kg ha⁻¹ N; 40 kg ha⁻¹ P₂O₅ and 100 kg ha⁻¹ K₂O (hereinafter 20-40-100 NPK) was applied. In the harvest years the following fertilisation scheme was used: 70-50-50 NPK in the spring after vegetation recovery; N60 after the 1st and 2nd mowing; 10-40-80 NPK after the last mowing in September. Thus, during each season, the total amount of fertiliser 200-90-130 NPK per season was applied.

During the season, various features for the ryegrass swards were scored visually, including: regrowth in spring and after harvesting; intensity of culm formation in the aftermath; crown rust (*Puccinia coronata*) susceptibility; intensity of grass greening or grass health, etc. For the visual assessment, a 9-point scale was used: lower marks indicate a less pronounced trait expression, while higher marks indicate a more pronounced trait expression. Rust susceptibility was assessed according to the methodology of EUCARPIA Multisite Rust evaluation (Schubiger *et al.*, 2010). A scale from point 1 to 9 was used, where: 1 – no rust disease, 2 – traces of rust, 3–5% of the leaf surface is covered with rust pustules, 4–10%, 5–25%, 6–40%, 7–60%, 8–75%, 9 – more than 75% of the foliage covered with rust, the grass is dominated by necrotic leaves. The rating values represent a relative estimate of visual assessment of sward area in the plot occupied by rust pustules. The heading date, when first shoots emerged, was fixed and it was expressed as a number of days from the 1st of May. The persistence or sward cover was determined by visual assessment of the proportion of area covered by perennial ryegrass plants, expressed in %.

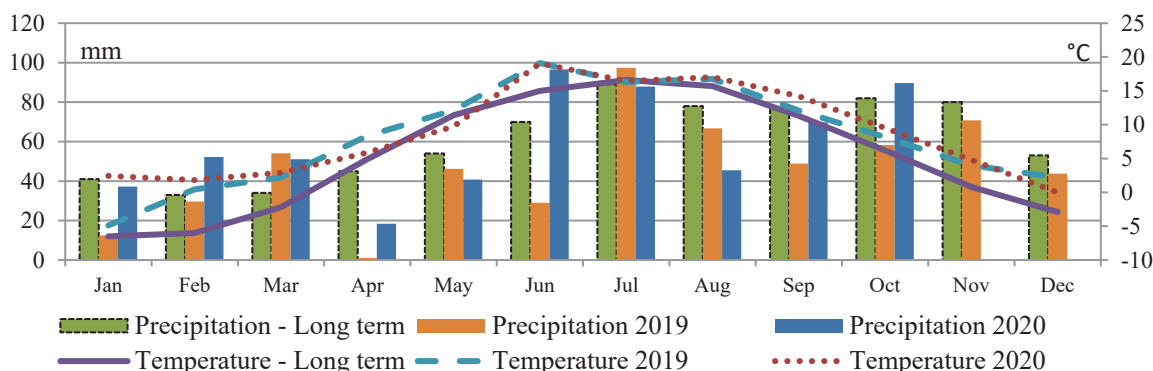


Figure 1. Amount of precipitation and average air temperature by months in 2019–2020 in comparison with long-term averages (Skriveri weather station data).

The registration of DM yield was performed in three mowings in the 1st ley year (2019) and four mowings in the 2nd ley year (2020) using the experimental green mass harvester 'Haldrup'. To determine the DM content, the green mass samples, approximately 500 g, from each plot before mowing were taken, weighed and placed in drying cabinets at 55 °C. Feed quality for dry matter samples was determined: crude protein (LVS EN ISO 5983-2: 2009); neutrally detergent fiber – NDF (LVS EN ISO16472: 2006); acid detergent fiber – ADF (LVS ENISO13906: 2008). Net energy for lactation (NEL), net energy for maintenance (NEM), net energy gain (NEG), DM digestibility, DM intake capacity (DMI) and relative feed value (RFV) were determined using the calculation methodology (Summary of feed..., 2013).

Results were analysed by ANOVA with a significance level of 0.05. For the evaluation of data obtained, the tests of statistically significant differences (LSD_{0.05}) were used.

To characterize meteorological conditions, the amount of precipitation by months and the average monthly air temperatures are listed (Figure 1). In both, the 1st ley year (2019) and the 2nd ley year (2020), the average air temperatures in winter and summer months were generally higher than the long-term averages. The exception was May of 2020, when the air temperature was below the long-term average, but this did not prevent grass growth. In terms of precipitation, the vegetation period of 2019 can be assessed as atypically dry – almost all months from April until the end of year, the monthly precipitation was well below the long-term averages. The season of 2020 also started with reduced rainfall: in April and May the amount of precipitation was well below the long-term average. In the following months of the season, precipitation normalized: June was rich in rainfall, when it fell by 30 mm more than usual. August was dry, but precipitation in September and October was similar to long-term averages. In general, the precipitation in vegetation period 2020 can be considered as typical.

Results and Discussions

In terms of heading time, perennial ryegrass genotypes differed within six days: the heading date for earliest 'LIA 58' fixed on the 29th day; for latest ('Raminta', 'LVA02526' and 'LVA 1058') – on the 34th day, calculating from the 1st May. For most genotypes heading date was fixed on the 31st–33rd day, for interspecific hybrid varieties – 'Saikava' and 'Vizule' – on the 31st day (Table 1).

Growth rate ranged from 6.4 to 9.0 points in spring and from 6.0 to 9.0 points after the 1st cut (Table 1). The Lp 'Elena DS' and the hybrid ryegrass 'Saikava' grew more intensively both in spring and after mowing

(scored with 9.0 points). Lp 'SW Birger' also grew rapidly (8.0). Lp 'EST 50' (8.0), 'Vir 51515' (7.5), 'Vir 50929' (7.5), 'Verseka' (7.5), 'Raite' (7.5) stood out in the 2nd cut. Both interspecific hybrid varieties 'Saikava' and 'Vizule' also had intensive regrowth in the 2nd cut (7.5 and 8.5 points). Intensive regrowth allows the variety to compete better with weeds and overcome other stressors, and usually it promotes higher yields.

The characteristic feature for Lp is more or less intensive development of generative shoots in aftermath, while *Festuca* hardly forms them (Berzins *et al.*, 2019). With each subsequent mowing, the intensity of culm development decreases. In the 3rd cut the intensity of culm development varied widely – from 2.9 to 8.6 points. Particularly intensive culming was observed for Lp 'Elena DS' (8.6); several Lp genotypes were evaluated with 4.5 to 6.0 points. Very weak culm development in the 3rd cut was noticed for 'Vir 51516' (2.9), 'EST 158' (3.0) and 'Garbor' (3.0). Genetic material with such characteristics could be used in the development of pasture and ornamental or lawn-type varieties. The intensity of culm development of interspecific hybrid varieties 'Saikava' and 'Vizule' in the 3rd cut was assessed as moderately intensive, it ranged from 4.9 to 5.0 points.

In the first ley years perennial ryegrass persists relatively well, especially under favorable wintering conditions (Lemežiene *et al.*, 2004; Berzins *et al.*, 2018). In the years of the study, winters in Latvia were unusually warm, the average air temperature significantly exceeded the long-term averages (Figure 1), and there was no pronounced black-frost periods. The vegetation season of 2019 was extremely dry, which affected the growth rate, but not the persistence. The cover of the evaluated genotypes in the autumn of the 2nd ley year ranged from 74% to 91%. Significantly ($p < 0.05$) denser swards were formed by varieties 'Raite' and 'Vifelt', its coverage was 91%. The most thinned was the sward of Lp 'Elena DS' (74%). Varieties of interspecific hybrids 'Saikava' and 'Vizule' in the 2nd ley year persisted well, the cover for both varieties was estimated as 81% (Table 1).

During the warm and wet seasons, ryegrass tends to be infected with various types of rust. This can be reduced by appropriate agronomic techniques, but experience shows that a very important role is played by genotype (Kemešytė, Statkevičiūtė, & Jaškūnė, 2019). In the process of breeding material evaluation, high attention is paid to rust resistance. In the trial the susceptibility to crown rust was evaluated (1–9 points); therefore, the genotypes with lower marks have higher resistance. Ratings ranged from 2.0 to 6.5 points. More resistant to crown rust in the conditions of 2019 were Lp 'Ovambo' (2.0) and 'Vifelt' (2.1). For interspecific hybrids, rust susceptibility was

Table 1

Assessment of *L. perenne* and ×*Festulium* varieties and genebank accessions in two ley years

Genotypes	Heading, days from 1 st of May	Regrowth, points (1-9)		Culms in the 3 rd cut, points	Sward cover in the 2 nd LY**, %	Crown rust susceptibility in the 3 rd cut (1 st LY), points	Grass health (2 nd LY), points
		in spring	after the 1 st cut				
SW Birger	31	8.0b*	6.0e	4.4cde	83abcd	3.5bcd	6.2abc
Raite	33	7.0cd	7.5bcd	4.5bcde	91a	4.6ab	6.0abc
Elena DS	32	9.0a	9.0a	8.6a	74d	3.6bcd	6.4abc
Alduva	31	6.9cd	6.5de	6.0b	80bcd	3.6bcd	5.9abc
Verseka	31	7.6 bc	7.5bcd	5.1 bc	79bcd	4.9ab	4.6cd
Garbor	31	6.5d	6.5de	3.0e	80bcd	2.6cd	5.3abcd
Ovambo	32	7.0cd	6.5de	3.1de	88ab	2.0d	7.1a
Vifelt	32	7.1cd	6.5de	4.5bcde	91a	2.1d	6.1abc
LIA 58	29	7.1cd	6.5de	3.5cde	76cd	3.3bcd	5.4abcd
Vir 50774	31	6.9cd	6.5de	5.0bc	81abcd	2.6cd	5.0abcd
EST 158	33	7.4 bc	7.0cde	3.0e	79bcd	3.2bcd	5.2abcd
Vir 51515	33	7.5 bc	7.5bcd	4.4bcde	81abcd	4.4bc	5.4abcd
EST 50	33	6.4d	8.0abc	4.0cde	82abcd	4.1bc	5.6abcd
Vir 51516	33	7.1cd	7.0cde	2.9e	84abc	4.8ab	5.1abcd
Vir 50929	33	7.0cd	7.5bcd	4.5bcde	82 abcd	4.4bc	4.6cd
LVA 02526	34	7.0cd	8.0abc	3.4cde	80bcd	6.5a	4.9bcd
LIA 1058	34	7.0cd	6.0e	4.1cde	84abcd	4.2bc	3.7d
155238	33	6.4d	6.5de	4.0cde	81abcd	4.4bc	6.5abc
Raminta	34	6.5d	7.0cde	4.0 cde	87abc	4.4bc	6.9ab
Saikava	31	9.0a	8.5ab	4.9bcd	81abcd	3.8bcd	6.8ab
Vizule	31	8.1 b	7.5bcd	5.0bcd	81abcd	4.5bc	7.0a
LSD _{0.05}	1.4	0.54	0.75	1.38	7.7	1.41	1.51

*a, b, c,... – Mean values followed by different letters in each column differ significantly from each other at the $p < 0.05$;
**LY – ley year

moderate – 3.8 points for ‘Saikava’ and 4.5 points for ‘Vizule’. In the 2nd ley year, the weather conditions were such that a pronounced outbreak of rust infection was not provoked, but in autumn significant differences in terms of greening or sward health there were observed, the ratings ranged from 3.7 to 7.1 points. The healthiest swards were developed by Lp ‘Ovambo’ (7.1) and ‘Raminta’ (6.9); and Fl ‘Vizule’ (7.0) and ‘Saikava’ (6.8) (Table 1).

The average dry matter (DM) yield in the two years of use ranged from 9.06 to 11.4 t ha⁻¹, depending on the genotype. More productive were Lp ‘SW Birger’ and ‘Elena DS’; significantly ($p < 0.05$) lower DM yield was found for Lp ‘No 155238’, ‘EST 158’, and ‘Ovambo 1’ (Table 2). Usually in the 1st ley year perennial ryegrass grows particularly intensively; however, the prolonged drought in 2019 contributed to only three harvests. In the 2nd ley year, the humidity conditions were much more favorable, there was a possibility to harvest four mowings. If we compare the

average yields of Lp and Fl, it can be concluded that there were no significant DM yield differences in the first two years. Slightly higher DM yield on average in the 1st and 2nd ley year was provided by Fl: 10.96 / 10.56 and 10.32 / 10.05 t ha⁻¹ Fl / Lp, respectively. Productivity and persistence of forage grasses is mainly determined by the genetic potential of species and varieties (Moser & Hoveland, 1996).

The highest proportion of DM yield, similar to other grass species, perennial ryegrass provides in the 1st harvest. In this experiment, the average DM yield of the 1st cut was 58% of the total DM yield (Figure 2). Depending on the genotype, it slightly varied between 56 and 62%, calculated on the basis of the average DM yield over two years. The yield proportion of the 2nd and 3rd harvests were relatively similar, 21% and 17%, respectively (Figure 2). The 4th harvest in the 2nd ley year was only 4% of the total yield. Although sometimes the last harvest does not give a significant increase in the total yield, it is important to mow it in

Table 2

Dry matter yield of *L. perenne* and ×*Festulium* varieties and genebank accessions in two ley years

Genotype	1 st ley year, t ha ⁻¹	2 nd ley year, t ha ⁻¹	An average in two ley years	
			t ha ⁻¹	% to control
<i>Lolium perenne</i> (Lp)				
SW Birger	11.48 ^{ab}	11.27 ^{ab}	11.38 ^a	100
Raite	10.13 ^{bc}	10.48 ^{abc}	10.30 ^{abcd}	91
Elena DS	11.30 ^{ab}	11.50 ^a	11.40 ^a	100
Alduva	10.35 ^{abc}	10.46 ^{abc}	10.40 ^{abcd}	91
Verseka	10.88 ^{abc}	10.14 ^{abc}	10.51 ^{abcd}	92
Garbor	12.15 ^a	9.87 ^{abc}	11.01 ^{ab}	97
Ovambo 1	9.70 ^{bc}	9.01 ^{bc}	9.35 ^{bcd}	82
Vifelt	10.75 ^{abc}	10.50 ^{abc}	10.62 ^{abcd}	93
LIA 58	10.32 ^{bc}	9.40 ^{abc}	9.86 ^{abcd}	87
Vir 50774	10.76 ^{abc}	10.24 ^{abc}	10.50 ^{abcd}	92
EST 158	9.36 ^c	9.07 ^{bc}	9.21 ^{cd}	81
Vir 51515	10.48 ^{abc}	10.04 ^{abc}	10.26 ^{abcd}	90
EST 50	11.27 ^{ab}	10.96 ^{abc}	11.12 ^a	98
Vir 51516	9.96 ^{bc}	10.51 ^{abc}	10.23 ^{abcd}	90
Vir 50929	10.76 ^{abc}	9.83 ^{abc}	10.29 ^{abcd}	90
LVA02526	10.14 ^{bc}	9.96 ^{abc}	10.05 ^{abcd}	88
LIA 1058	10.99 ^{abc}	8.98 ^{bc}	9.99 ^{abcd}	88
No155238	9.30 ^c	8.81 ^c	9.06 ^d	80
Raminta	10.57 ^{abc}	9.87 ^{abc}	10.22 ^{abcd}	90
<i>Festulium</i> (F1)				
Saikava	11.18 ^{ab}	10.52 ^{abc}	10.85 ^{abc}	95
Vizule	10.73 ^{abc}	10.11 ^{abc}	10.42 ^{abcd}	92
An average of Lp	10.56	10.05	10.30	
An average of F1	10.96	10.32	10.64	
LSD0.05	1.32	1.72	1.26	

*a, b, c,... – The mean values in each column followed by different letters differ significantly from each other at the $p < 0.05$

order to provide better overwintering. It is known that large green mass, left for the winter, can cause snow mold and other infectious diseases, which generally worsen winter hardiness and, consequently, the persistence. The forage quality of the 1st mowing was evaluated. The content of crude protein (CP) ranged from 6.99 to 10.68% for Lp; slightly lower (7.84 to 8.31%) it was for F1 (Table 3). The highest (>10%) CP content was provided by Lp genotypes ‘LIA 1058’ and ‘Vir 51515’. The ADF fraction negatively correlated with the digestibility of ingested feed. On the other hand, with increase of NDF content its intake decreases. For high-quality dairy cows, the ADF should not exceed 40% in the dry matter, while the NDF should be below 50%. Exceeding these values for fiber fractions in fodder will result in less food being eaten and less processing of what

is eaten. In this experiment, the ADF for Lp ranged from 19.92% to 25.11%, while the NDF ranged from 38.79 to 46.74%. This proves that Lp provides a high-quality fodder. The dry matter value of interspecific hybrids ‘Saikava’ and ‘Vizule’ was also high enough. Net energy for lactation (NEL), which is very important for dairy cows ration compilation, was relatively similar for all genotypes, ranging from 6.6 to 7.02 MJ kg⁻¹. Dry matter digestibility ranged from 69.34 to 73.38%. Dry matter intake (DMI) indicates the amount of dry matter that an animal will be able to eat. It depends on how quickly the fodder is digested and passes through the intestinal tract. This indicator is most directly affected by NDF – as NDF increases, fodder DM intake capacity decreases. In the experiment the DMI ranged from 2.57 to 3.09% of cow body weight.

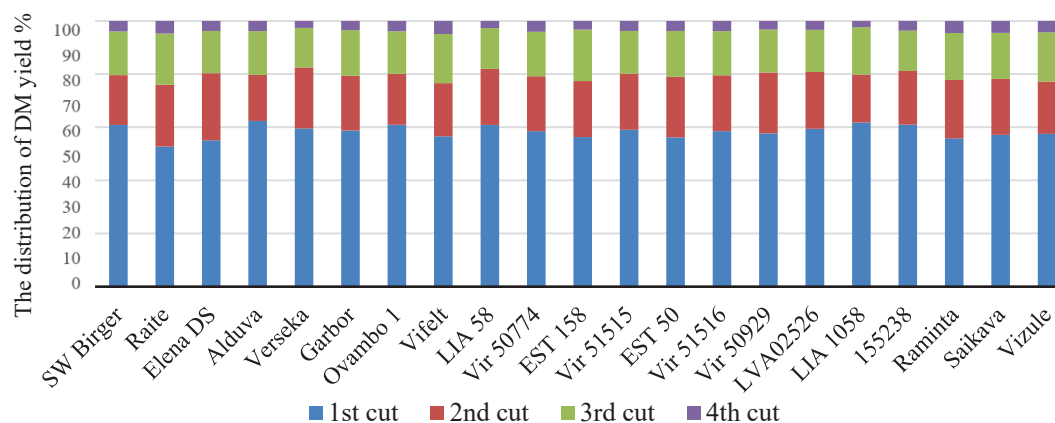


Figure 2. The distribution of dry matter (DM) yield by mowings in two ley years.

The Relative Feed Value (RFV) index is used to compare feed, taking into account the digestibility and intake of the feed. The higher this index, the higher the value of fodder. The threshold is 100, below which

feed is considered to be of low quality (Summary of feed..., 2013). High-yielding dairy cows need a feed with an index above 124. In the experiment, for Lp it was significantly higher and ranged between 149 and

Table 3

Fodder quality of the 1st cut of *Lolium perenne* and ×*Festulolium* genotypes

Genotype	Crude protein, %	NDF, %	ADF, %	NEL, MJ kg ⁻¹	NEM, MJ kg ⁻¹	NEG, MJ kg ⁻¹	DM digestibility, %	DMI, % of cow body weight	RFV
W Birger	9.09	42.75	23.85	6.71	7.34	4.32	70.32	2.81	153
Garbor	7.15	39.01	19.92	7.02	7.71	4.69	73.38	3.08	175
Raite	9.59	44.05	23.61	6.73	7.36	4.34	70.51	2.72	149
Elena DS	7.16	42.57	22.75	6.79	7.45	4.43	71.18	2.82	156
Alduva	7.71	42.08	21.95	6.86	7.52	4.50	71.80	2.85	159
Verseka	6.99	40.07	21.75	6.87	7.54	4.52	71.96	2.99	167
Ovambo 1	7.40	42.17	21.85	6.87	7.53	4.51	71.88	2.85	159
Vifelt	9.14	38.79	21.94	6.86	7.52	4.50	71.81	3.09	172
LIA 58	8.29	43.91	22.95	6.78	7.43	4.41	71.02	2.73	150
Vir 50774	9.44	42.77	23.38	6.74	7.39	4.37	70.69	2.81	154
EST 158	7.96	41.95	21.86	6.87	7.53	4.51	71.87	2.86	159
Vir 51515	10.10	41.36	21.72	6.88	7.54	4.52	71.98	2.90	162
EST 50	8.42	42.15	22.31	6.83	7.49	4.47	71.52	2.85	158
Vir 51516	7.56	41.80	22.60	6.81	7.46	4.44	71.29	2.87	159
Vir 50929	8.85	39.67	20.82	6.95	7.63	4.61	72.68	3.02	170
LVA02526	7.93	43.18	22.86	6.79	7.44	4.41	71.09	2.78	153
LIA 1058	10.68	40.24	21.37	6.90	7.58	4.56	72.25	2.98	167
No155238	9.29	42.42	22.43	6.82	7.48	4.46	71.43	2.83	157
Raminta	9.90	41.97	22.26	6.83	7.49	4.47	71.56	2.86	159
Saikava	7.84	46.74	25.11	6.61	7.22	4.20	69.34	2.57	138
Vizule	8.31	45.07	24.01	6.69	7.33	4.31	70.20	2.66	145
An average	8.51	42.13	22.44	6.82	7.48	4.45	71.89	2.85	158
Min	6.99	38.79	19.92	6.61	7.22	4.20	69.34	2.57	138
Max	10.68	46.74	25.11	7.02	7.71	4.69	73.38	3.09	175

175. The RFV index was relatively lower for the Fl 'Saikava' (138) and 'Vizule' (145); however, they also provided high-quality fodder. Assessing the forage quality indicators as a whole, it can be concluded that the highest forage quality was found for Lp 'Raite', 'Vifelt' and 'Vir 50929'. Other genotypes also performed very well, which confirms that by mowing perennial ryegrass at the beginning of heading, it is possible to obtain high-quality fodder.

Conclusions

Currently, two-year data have been collected, and we can conclude that the highest *Lolium perenne* (Lp) DM yield proportion is provided in the 1st cut giving 58% of the total DM yield. The yields of the 2nd and 3rd cuts were similar, 21% and 17%, respectively. Lp provided satisfactory DM yields – on average 10.56 and 10.05 t ha⁻¹ in the 1st and in the 2nd ley year, respectively. Lp DM yields did not differ significantly from \times *Festulolium* (Fl).

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In the first years of use, no significant differences were found between ryegrass and grass interspecies hybrids in terms of grass quality and forage value. ADF for Lp ranged from 19.92% to 25.11%, while NDF from 38.79% to 46.74%. This proves that ryegrass provides high-quality fodder. The Relative Feed Value (RFV) index for Lp was high, it ranged between 149 and 175, slightly lower it was for Fl, on average 142.

The research should be continued to determine the more persistent and productive genotypes, especially in harsher wintering conditions, as well as to compare the performance of Lp with Fl in the later years.

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AGROECOLOGICAL PRACTICES AS SUSTAINABLE MANAGEMENT OF COMMON NATURAL RESOURCES: THE CASE OF LATVIAN PERMACULTURE MOVEMENT

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Abstract

Scientific evidence is robust about the environmentally destructive side-effects of the current industrial civilization and that requires radical actions to safeguard sustainable management of natural resources and liveable Planet Earth. Agroecology as a broader movement serves some of this role in demonstrating alternative practices in food production and ecosystem management. This paper demonstrates that the permaculture movement in Latvia is developing as a recognized alternative on the pathway to solutions, linking to the work elsewhere done on management of common natural resources – the things that no one owns and are shared by everyone. The author have explored the development of the permaculture movement in Latvia since its first roots in the late 2000s and the establishment of the Latvian Permaculture Association (LPA) in 2011. The contribution of the movement manifests itself in diverse aspects. It unifies various sustainability-oriented people, grounds itself in locality and traditions, organises practically oriented events to upskill people, and collaborates with Latvian environmental organisations and internationally. Within the research the author consciously opted for an in-depth involvement and co-creation of initiatives within the permaculture movement, leading the LPA since 2016 and organizing multiple events and workshops. That leads to further reflections on the role and necessity for participatory action research for sustainability transformations and common natural resources.

Key words: agroecology, permaculture, commons, regeneration, sustainability transformations, participatory action research.

Introduction

‘The philosophy behind permaculture is one of working with, rather than against, nature’ (Mollison, 1988). World scientists are issuing ‘warnings to humanity’ (Ripple *et al.*, 2017) that we are indeed working ‘against nature’ – many concerns relate to the current land management practices that are affected by the climate crisis (IPCC, 2018; IPCC, 2019), contributing to the ongoing biological annihilation (Ceballos *et al.*, 2017) and one million species at risk of extinction (IPBES, 2019) as side-effects of our development and growth (Beck, 2009). One of the worldwide responses to such dilemmas is agroecology and within it the permaculture movement (Mollison & Holmgren, 1978) which is, however, little covered in the scientific literature (Ferguson & Lovell, 2014).

It is reasonable to argue that ‘permaculture’ has been practiced for thousands of years and still is somewhere practiced by people who have never heard of permaculture. The term itself was formulated in the 1970s by two Australians, Bill Mollison and David Holmgren (1978). Initially, it was predominantly focused on the agricultural aspects as in ‘permanent agriculture’ and attempts to mimic natural ecosystems, for example, in forest gardens, but it has developed over time and continues to change and develop. By the early 1990s permaculture already has been redefined as ‘...a design system for creating sustainable human environments. The word itself is a contraction not only of permanent agriculture but also of permanent culture, as cultures cannot survive long without a

sustainable agricultural base and land use ethic.’ (Mollison & Slay, 1991).

Permaculture as both philosophical and practical framework is establishing itself as reliable in transformative action (Henfrey, 2018). Permaculture is probably the best-known movement within a broader global agroecological movement but has been relatively neglected in the scientific literature in spite of the high level of general interest and widespread practice in already most of the world (Ferguson & Lovell, 2014; Hathaway, 2016; Rhodes, 2012). For example, it is one of the key inspirations in the development of the international Transition Network that now covers more than 50 countries and thousands of transition groups (Hopkins, 2011). Such examples highlight the role the permaculture movement can play beyond the focus on alternative agroecological practices and provide a broader ethical and philosophical guidance to transcend current unsustainable paradigms (Gopel, 2016) and develop regenerative ‘permanent cultures’. In essence, permaculture is not only about particular practices, but about changes in the whole lifestyles to be regenerative – to turn the human negative ecological impact into a positive one.

A common line of criticism is summed up by Ferguson and Lovell (2014) who claim that permaculture literature tends to have ‘simple solution populism’. In other words, solutions to environmental and social crises are both simple and known and hence permaculture only requires the recombination of the existing knowledge rather than the generation of new knowledge (Mollison & Holmgren, 1978).

On the contrary, in permaculture literature academic institutions and researchers are commonly criticized for conservatism, slow pace of change, lack of vision, and strong ties to unsustainable corporate interests (Mollison & Holmgren, 1978; Mollison, 1988; Shepard, 2013). One of the origins for this stance is the university colleagues' rejection of Mollison's plea for a cross-disciplinary holistic approach in the 1970s. His work was one of the first attempts to develop a regenerative design approach that drew on the knowledge of traditional cultures while adapting to the opportunities of new technologies and systems thinking.

The core ethics of permaculture can be summarised in the threefold: 'Earth care, people care and fair share' (Holmgren, 2002). That resonates with ongoing discussion in environmental philosophy and ethics about the risks associated with anthropocentrism and related risks of ecosystem and resource exploitation (Keller, 2010; Kingsnorth, 2017). It is essential to see permaculture not as a revolutionary novel approach to farming or living, but as an overall framework that brings together many diverse environmental ideas in a coherent pattern. Most of the specific ideas and practices under the heading of permaculture are not unique to it and were not originated by people who call themselves 'permaculturists' (Whitefield, 2004). Ironically, in that sense permaculture does reflect the ideal of scientific knowledge accumulation in Newtonian 'standing on the shoulders of giants', however, permaculture covers a broad spectrum of disciplines and focuses on human and ecosystem long-term well-being and permanent solutions through practical action. Therefore, it is useful as a holistic framework to advance sustainability transformations and management of common natural resources in Latvia and this article demonstrates the current achievements and challenges.

As mentioned above, permaculture is relatively neglected in the scientific literature internationally and in Latvia and hence this paper aims to summarise the history and development of the permaculture movement in Latvia, its support for transformative regenerative actions, and contributions to the management of common natural resources through participatory action research approach.

Materials and Methods

This paper is based on an ongoing participatory action research with a wide spectrum of involvement avenues in sustainability-oriented initiatives in Latvia beginning in 2016. The research was initiated within a broader research network – Marie Curie Innovative Training Network SUSPLACE (www.susplace.net) and is further advanced during the Latvian Council of Science funded project 'Ready for change?

Sustainable management of common natural resources (RfC)'. The logic of such participatory action research includes, firstly, synthesis of natural and climate science evidence of the immense sustainability transformations required and, secondly, engagement in active knowledge brokerage and societal change advancement, including management of commons.

Essentials for action-oriented, transformations and climate change research, summarized on the basis of individual and collective outputs in two-year collaboration of almost 50 scientists (Fazey *et al.*, 2018) are reflected in much of the author's work carried out since 2016 in Latvia. The essentials recommended are based on the expressed need for 'massive upscaling of research that can rapidly enhance learning about transformations:

- 1) Focus on transformations to low-carbon, resilient living;
- 2) Focus on solution processes;
- 3) Focus on 'how to' practical knowledge;
- 4) Approach research as occurring from within the system being intervened;
- 5) Work with normative aspects;
- 6) Seek to transcend current thinking;
- 7) Take a multi-faceted approach to understand and shape change;
- 8) Acknowledge the value of alternative roles of researchers;
- 9) Encourage second-order experimentation;
- 10) Be reflexive'

(Fazey *et al.*, 2018). Such essentials indicate that research itself needs to undergo fundamental changes if it wants to contribute to sustainability transformations and regeneration.

The summary of Julia Wittmayer methodological contribution in her research on 'Transition Management, Action Research and Actor Roles: Understanding local sustainability transitions' (2016) outlines the types of advantages and challenges the author is also experiencing in the research – action-oriented approaches are 'creating spaces for reflexivity, interaction and learning and in generating scientific, social and reflexive knowledge as well as actual action and thus supporting sustainability transitions whilst studying them. These approaches are challenging in the actual operationalization in messy, contested and diverse contexts, which put high demands on researcher's identity and integrity' (Wittmayer, 2016: 260).

A particular difficulty of research addressing societal problems arising from sustainability problems is the explicit normative component that inevitably arises. A researcher spending years studying sustainability challenges or regeneration potential is likely to struggle to provide an open-ended process in discussing sustainability definition and approaches, but instead will be inclined towards a more normative standpoint stemming from the informed position as to what actions should be preferential to lead to more sustainability. Such paradoxes 'cannot be solved in general terms but only through being embedded in a specific local context, which is where questions of

ethics and normativity arise' (Wittmayer, 2016: 255).

Therefore, this paper provides insights in attempts to do so in the particular circumstances of Latvia – researching the ongoing processes and leading or co-creating multiple activities since 2016:

a) two internationally recognised Permaculture Design Certificate (PDC) courses in 2017; b) The Diploma in Applied Permaculture process initiated in 2018 and the first Diploma holder graduation in 2020; c) Plans for the PDC course in Latvian tailored to the local needs in 2021; d) five annual permaculture festivals with multiple lectures and practical workshops; e) more than ten Rocket Mass Heater (RMH) practical workshops; f) six successful project applications and implementation (completed and ongoing – Nordplus, Erasmus+, LEADER LAGs, Latvian Environmental Protection Fund, Society Integration Foundation); g) >10 national-level radio appearances on permaculture, climate change and degrowth; h) more than ten university guest lectures in four different Latvian universities to students of economics, management, sociology, agriculture and eco-technologies – about sustainability science, permaculture, degrowth and participatory action research; i) more than ten public lectures in various settings, for example, the annual discussion festival LAMPA; j) Leading the Latvian Permaculture Association (LPA) as its chairman since 2016; k) Leading the multifunctional open permaculture homestead 'Zadiņi' and the foundation 'Zadiņi' since 2018.

Co-created events and activities are providing diverse sources of information and data. Firstly, photos and video material of events and daily work. Secondly, in-depth insights into the day-to-day operation of permaculture activists and homesteads (including recorded interview and discussion material). Thirdly, evaluation material from workshop participants (quantitative and qualitative). Fourthly, overall development of in-depth insight about the people interested in permaculture practices and their individual steps towards sustainability and regeneration – from multiple workshops, seminars and the permaculture festivals.

However, the aim in the participatory action research process is not only to document some of the sustainability-oriented actions based on people's claims in interviews, evaluations or discussions, but predominantly to contribute to sustainability transformations and management of common natural resources in the society through co-creation of activities, events, workshops and longer lasting collaborative networks as summarised above.

Results and Discussion

The LPA was chosen in the author's research and activism as one of key entry points to contribute to

sustainability transformation and management of common natural resources in Latvia. The LPA is founded in late 2011. However, the first encounters with permaculture as a theoretical and practical framework happened when Latvian organic farmers visited Austria in late 2000s. In the foundation of the LPA some farmers were joined by various enthusiasts across the country who had encountered permaculture as a part of solution to the various sustainability problems of the world that they had been trying to understand. The LPA includes a wide variety of Latvian population, foreigners in Latvia and Latvians living abroad.

The author has been elected chairman of it since the spring 2016, and the number of its members doubled from 68 to 150 in early 2021. 23% of its members live in Riga, 23% in a near proximity to it – Pierīga, 27% live in the Vidzeme region and less in other regions – 11% in Kurzeme, 7% in Latgale and Zemgale and 4% abroad.

The new LPA website (www.permakultura.lv) was launched in April 2017 and its visitors have more than doubled if to compare the April-December 2017 with the April-December 2018 and increased further in 2019 and 2020. There are remarkable daily visitor peaks before bigger events and after public appearances on the radio or other media about permaculture. The Facebook Latvian permaculture group (www.facebook.com/permakultura.lv) has also multiplied its follower numbers since 2016, exceeding 2500 in early 2021.

These quantifications correspond to qualitative research evidence that the LPA has become recognised as a practically oriented environmental Non-Governmental Organisation (NGO) among other Latvian environmental organisations and multiple people from the organisation are regularly invited to relevant discussions, film screenings, petition signings and protests. This is the privilege of a relatively small country like Latvia that it is possible to quickly personally get to know a whole range of people if the activities are relevant, ambitious and compelling.

Further recognition of the permaculture practices as alternatives in agricultural practices and management of commons is through the work of LPA members within the Latvian Rural Advisory and Training Centre (LLKC). In 2020 and 2021, there have already been multiple LLKC seminars including topics of permaculture and agroecology, and there are further expressions of interest from the regional LLKC branches. The attitude within the LLKC has been significantly shifting, especially within the last five years in recognition of need and feasibility of agricultural and resource management practices that are regenerative (organic farming, agroecology, permaculture) and help to reduce the risks of

environmental breakdown and improve the capacity to somewhat adapt to that.

Many of the practices in permaculture are aiming for regeneration as indicated in the sub-title 'Principles and pathways beyond sustainability' and re-appearing throughout the 12 core permaculture principles:

1. Observe and interact; 2. Catch and store energy;
3. Obtain a yield; 4. Apply self-regulation and accept feedback;
5. Use and value renewable resources and services;
6. Produce no waste; 7. Design from patterns to details;
8. Integrate rather than segregate; 9. Use small and slow solutions;
10. Use and value diversity;
11. Use edges and value the marginal; 12. Creatively use and respond to change (Holmgren, 2002).

This is not a strict list of principles every 'permaculturist' should or does follow, but rather this is an important guide towards an overall ecologically aware and embodied lifestyle. Some people in the organic farming movement admit that it often lacks the coherent set of ecological ideas/worldviews, or, in other words, ideology. Permaculture is useful in providing this encouraging ideology and personal integrity for any actions that one takes.

The LPA is also a member or in regular contacts with multiple relevant international organisations – European Permaculture Network (EUPN), ECOLISE Network, Global Ecovillage Network, Baltic Ecovillage Network, Transition Network, Nordic Permaculture Institute, Danish Ecovillage Association, Finnish Permaculture Association, Estonian Permaculture Association (founded in April 2018), Small Footprint Ecovillage (Estonia), Suderbyn Permaculture Ecovillage (Sweden) and others.

Together with different LPA members there have been several successful project applications that are oriented towards achieving aims that are aligning with the permaculture principles, resilient, regenerative lifestyles, and sustainable management of common resources, for example:

1. 'School gardens for Latvian Centenary' – creation of co-designed permaculture school gardens by four Latvian schools and website creation with advice for other schools to follow the example (www.skoludarzi.net, Latvian Environmental Protection Fund, 2017–2018);
2. 'Growing Seed Savers: Baltic-Nordic Seed Savers Education Innovation' – development of seed saving database, international experience exchange and popularisation of seed sharing practices with partners in Estonia, Lithuania and Denmark (<https://growingseedsavers.org>, Nordplus, 2018–2020);
3. 'OFF-GRID: Renewable Energy Do-It-Yourself for rural development' – targeting specifically self-sufficiency energetically and technically of those that are not already financially privileged and running practical workshops in three Latvian regions, creation of open source paper and online handbook

for self-build installations and devices; in total 10 partners in 5 Baltic Sea Region countries – Sweden, Finland, Estonia, Latvia and Lithuania (LEADER LAGs, 2018–2020);

4. 'Support to the Latvian Permaculture Association for popularisation of sustainable agriculture in Latvia' (www.permakultura.lv/ilgtspējīga-lauksaimniecība.html, www.mantots.permakultura.lv, Society Integration Foundation, 2020);
5. Media campaign 'Alive Earth' within the Society Integration Foundation (SIF) funded project with regular press releases, articles and social media posts throughout 2020 – regarding pesticide use, pesticide drift, sustainable agricultural practices etc. (<http://www.permakultura.lv/dzīva-zeme.html>);
6. 'Eco-active for Planet' – project coordinated by the NGO Trainers' Association in Poland, with partners from Czechia, Finland, Luxembourg (Erasmus+, 2020–2022).

There are multiple pathways of project implementation with the involvement of the LPA. Sometimes projects are submitted directly by the LPA, in other projects the LPA is included as the partner and on other occasions the projects are submitted through other NGOs of active LPA members or in collaboration with the Local Action Groups (LEADER). The active LPA members are very resourceful and persistent in trying to secure support for the ideas that make sense for rural resilience development and permaculture. Projects are predominantly initiated on the basis of advancing quicker the sustainability transformations that permaculturists would like to see anyway and that would be slower or not possible without the grant funding.

The overarching theme that enables the multi-stakeholder involvement is the openness for others to learn what is done in the homesteads of the LPA members and how the owners can inspire and empower others in reception of voluntary workers, aspiring back-to-the-landers, permaculture enthusiasts and journalists. Indeed, since 2016 permaculture related activities and places increasingly more often appear on local and national radio, TV and YouTube channel episodes as well as on newspaper and journal articles. The campaign 'Alive Earth' during 2020 was a particularly recognizable in that respect and resonated well with growing Latvian societal sentiments about the dangers of pesticide use and pesticide drift. Throughout the year both LPA official membership and following on Facebook was rising faster than in 2019 or 2018. The representatives from the State Plant Protection Service (www.vaad.gov.lv) that is in charge of permissions for plant protection substances and monitoring of their use in several personal discussions have admitted that the activity of people in reporting possible breaches in pesticide use has been unprecedented in 2020.

The continuous work through several LPA projects on the seed saving and heritage heirloom seeds is an important work in the direction of maintaining the plant genetic diversity as common pool resource. David Bollier also recognizes the work of the permaculture movement among other in resurrecting heirloom varieties (Bollier, 2014: 50). Annual seed exchanges in the beginning of the year is the longest-running LPA event for over a decade. In early 2020 this event was joined with the seed savers weekend-long training and in early 2021 this training was brought online with three whole-day sessions that brought more than 60 people in attendance.

The biggest annual event of the LPA is Permaculture Festival that was running for the 7th time in the summer 2020 (www.permakultura.lv/festivals.html). Since 2016 it is annually attended by 120–180 people and 30–50 of them are children, indicating about the friendly atmosphere for all generations and appeal that permaculture ideas are appreciated among families thinking of the future of their children. The festival traditionally includes a combination of lectures and practical workshops in a wide range of issues LPA members have expertise about – practitioners on the Diploma in Applied Permaculture pathway are forming the core group of teachers, supplemented by other active LPA members. The ongoing funded project outputs are always incorporated in the festival program, for example, the OFF-GRID project workshops were tailored with the 2019 and 2020 festival. Throughout the years there is a strong emphasis on practitioners and people speaking from their experience of applying various agroecological and permaculture theories into practice and Latvian climatic conditions. Practical workshops also include ‘forest walks’ or ‘field walks’ with lively discussions about the biological diversity of different ecosystems and what human management approaches can be to manage those common natural resources sustainably and regeneratively. The practices include sustainable forestry approaches without clear-cuts, forest gardens, silvo-pastures, holistic management of grazing systems and other approaches benefiting from various aspects of plant succession and mimicking ecosystem functioning.

Conclusions

In conclusion, this paper has explored the role of the permaculture movement in supporting regeneration, and it can be concluded that permaculture in Latvia is contributing to sustainability and management of

commons in several aspects. Firstly, the permaculture movement already reaches diverse types of people in Latvia, allowing them to relate to the movement – city dwellers, recent and aspiring ‘back-to-the-landers’, small town inhabitants, and rural people; each group finding different aspects of permaculture as useful for their further paths. Secondly, it roots itself in locality and traditions, building national-level recognition and trust through social activism and media appearances. Thirdly, there are multiple events that provide practical examples, know-how and empowers people to make further changes in their lives. Fourthly, the movement connects with other environmental organisations and strengthens the Latvian network acting on a broad range of environmental and climate issues. Fifthly, a national practitioner network and collaborative networks within the Baltic Sea region are continuously developing.

However, simultaneously several challenges arise. In spite of the successes and growing popularity, the permaculture movement in Latvia is largely driven by the above mentioned activists and a relatively narrow circle of skilled, experienced, motivated, and proactive people. The LPA has developed substantially as an organisation since 2016, but remains relatively vulnerable in its structural resilience. These are common issues in the NGO sector and grassroots activities in Latvia as a small country with a troubled history and still inexperienced civic society. The change and transformations can be driven fast, but simultaneously the successes can be fragile because of the dependency on relatively few leaders.

Furthermore, some criticism also relates to the scale of influence the permaculture movement has. It does contribute to lifestyle changes, sustainability transformations, regeneration and teaches about the management of common natural resources, but many people still struggle to alter their life status-quo in the face of dominant consumer-culture and permaculture risks to remain as the change factor for incremental change with the same unsustainable fundamentals. However, with the scale of the challenges, risks, and catastrophes ahead, the permaculture principles and practices are likely to maintain their appeal and assist in the much-needed sustainability transformations through reforms or further crises.

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VIRULENCE OF *PYRENOPHORA TRITICI-REPENTIS*: A MINIREVIEW

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Abstract

Pyrenophora tritici-repentis is a major wheat pathogen in all wheat (*Triticum* spp.) growing areas worldwide. Up to date, eight *P. tritici-repentis* races have been described based on chlorosis, necrosis, or both symptoms caused on race differential wheat genotypes: 'Glenlea', 6B662, 6B365, and 'Salamouni'. Symptom development on differential genotypes depends on the interaction of the pathogen's necrotrophic effectors named Ptr ToxA, Ptr ToxB, and Ptr ToxC with host susceptibility genes. Ptr ToxA is encoded by the single copy gene *ToxA* and induces necrosis on sensitive wheat cultivars. Ptr ToxB causes chlorosis and is encoded by the multicopy gene *ToxB*. The Ptr ToxC is the non-proteinaceous, polar, low molecular mass molecule that also induces chlorosis, but up to date, the gene encoding this toxin is unknown. Races producing Ptr ToxA are predominant in the global *Ptr* population. There are several reports about new putative races of *P. tritici-repentis* that do not conform with the current race system, so further research is required. This study aims to collect and systematise available information about the virulence and races of *P. tritici-repentis*.

Key words: races, necrotrophic effectors, population, tan spot, wheat.

Introduction

Tan spot caused by *Pyrenophora tritici-repentis* (*Ptr*), from the phylum *Ascomycota* order *Pleosporales* is a notable wheat foliar disease in all major wheat (*Triticum* spp.) growing regions (Ciuffetti *et al.*, 2014; Strelkov & Lamari, 2003). It is one of the most devastating wheat diseases in Latvia and Lithuania (Ronis *et al.*, 2009; Švarta *et al.*, 2020).

Besides wheat, triticale (\times *Triticosecale*), rye (*Secale cereale*), barley (*Hordeum vulgare*), also various grasses from *Poaceae* family are known as host plants of *Ptr* (Ali & Francl, 2003; Hosford, 1971; Krupinsky, 1982; Misra, Pandey, & Misra, 1979).

The first who described and isolated the asexual stage of this pathogen from *Elymus repens* was Diedicke in Germany in 1902 (Diedicke, 1902). Diedicke classified the newly found fungus as *Helminthosporium graminearum* Rab. ex Schlecht. f. sp. *tritici-repentis* Died., with *Pleospora trichostoma* (Fr.) Fuckel. as its teleomorph. In 1903, Diedicke renamed this species as *Helminthosporium tritici-repentis* Died. and *Pleospora tritici-repentis* Died. Later, in 1923, Drechsler classified it as *Pyrenophora tritici-repentis* (Died.) Drechs. based on setae presence on the fruiting body (pseudothecia). In 1928, the fungus asexual stage was isolated from wheat and identified as *Helminthosporium tritici-vulgaris* (Nisikado) by Nisikado. In 1930, Ito, based on conidia germination peculiarities, renamed *H. tritici-vulgaris* as *Drechslera tritici-vulgaris* (Hosford, 1981; Maraite, 1997). All synonyms for both morphs were revised by Shoemaker (1962) as *Pyrenophora tritici-repentis* (Died.) Drechs. for sexual state and *Drechslera tritici-repentis* (Died.) Shoem. for the asexual state (Hosford, 1981; Maraite, 1997). In 2014, the scientific community supported using the genus

name *Pyrenophora* over *Drechslera*, thus adopting *Pyrenophora tritici-repentis* (Died.) Drechs. as a sole name (holomorph) of the pathogen (Wijayawardene *et al.*, 2014).

Up to date 8 different *Ptr* races have been described, based on necrotrophic effectors (NEs) they produce and symptoms they cause on defined host-plant differential set (Lamari *et al.*, 2003). These NEs are called Ptr ToxA, Ptr ToxB, and Ptr ToxC and can cause two different symptoms on the host plants – necrosis and/or chlorosis (Lamari & Bernier, 1989).

The diversity of the pathogen's population is related to different aspects of disease development and control possibilities, such as overcoming cultivar resistance and sensitivity to fungicides. This study aims to collect and organise available information about *Ptr* populations to understand wheat-pathogen interactions better and gain knowledge for the adaptation of plant protection strategy.

Materials and Methods

In the present study a monographic approach was used. The results of worldwide research on the taxonomy, biology and population diversity focusing on the virulence of *Ptr* were summarised and analysed.

Results and Discussion

Races of P. tritici-repentis

Ptr can cause two different types of symptoms – necrosis and chlorosis. Lamari and Bernier (1989) proposed to group *Ptr* isolates into four pathotypes based on the expressed symptoms on a set of race-differential wheat genotypes. Initially, isolates belonging to pathotype 1 were thought to cause either extensive necrosis or extensive chlorosis (nec⁺ chl⁺),

until Lamari, Bernier and Smith (1991) reported that wheat genotypes are able to express both necrosis and chlorosis simultaneously. Isolates that induced only necrosis were grouped into pathotype 2 ($nec^+ chl^-$), while isolates that caused only chlorosis were considered pathotype 3 ($nec^- chl^+$). Avirulent isolates were classified as pathotype 4 ($nec^- chl^-$).

Sorting *Ptr* isolates into four pathotypes proved insufficient as Lamari *et al.* (1995) found chlorosis ($nec^- chl^+$) inducing isolates from Algeria, which had a different virulence pattern from previously described pathotype 3. These isolates were virulent on the wheat cultivar ‘Katepwa’ and avirulent on the line 6B365, which was directly opposite to pathotype 3, which caused chlorosis on 6B635 and was avirulent on ‘Katepwa’. Therefore, Lamari *et al.* (1995) proposed to use race designation to specify *Ptr* virulence (Table 1). Races 1, 2, 3 and 4 represent the formerly described four pathotypes; the newly characterised isolates were assigned as race 5. Race 6 combines the virulence patterns of races 3 and 5, as it causes extensive chlorosis on both ‘Katepwa’ and 6B635. Likewise, race 5 induces chlorosis on wheat line 6B662 that is resistant to the first four races (Strelkov *et al.*, 2002). Race 7 causes necrosis on ‘Glenlea’ and chlorosis on 6B662, combining the virulence patterns of races 2 and 5. Race 8 induces necrosis on ‘Glenlea’, and chlorosis on 6B662 and 6B365, combining the virulence of races 2, 5, and 3 (Lamari *et al.*, 2003; Lamari *et al.*, 2005).

Virulence factors of P. tritici-repentis

Necrotrophic effectors determine virulence factors of the known *Ptr* races (NEs), historically called host-selective toxins (HSTs) (Ciuffetti *et al.*, 2010; Tomas & Bockus, 1987). The set of race differential wheat genotypes defined by Lamari *et al.* (2003) is based on the symptoms expressed by these genotypes in response to the infection by a specific race of the pathogen (Table 1). Previous research (Ballance, Lamari, & Bernier, 1989; Effertz *et al.*, 2002; Orolaza, Lamari, & Ballance, 1995) revealed that these reactions follow an inverse-gene-for-gene model, as wheat sensitivity to the specific NEs produced by *Ptr* is determined by compatibility between NEs and host susceptibility genes, while insensitivity is observed if the host and NEs are incompatible (Lamari *et al.*, 2003). Ciuffetti *et al.* (1998) published a standardised nomenclature for *Ptr* virulence factors and genes involved to resolve problems arising from the multiple names for the same necrotrophic effector and the regulating gene. NEs are named as *Ptr* ToxA, *Ptr* ToxB, and *Ptr* ToxC in the order of their characterisation. The genes are named according to the NEs and encode *ToxA*, *ToxB*, *ToxC*, respectively (Ciuffetti *et al.*, 2014).

Ptr ToxA produced by races 1, 2, 7 and 8 induces necrosis on susceptible wheat cultivars (Lamari & Bernier, 1989; Lamari *et al.*, 2003). *Ptr* ToxA is a protein that is synthesized ribosomally and is encoded by a single *ToxA* gene. *ToxA* encodes a 23 amino acid signal peptide, a 38 amino acid (4.3 kDa) pro-domain

Table 1

The reaction of differential wheat genotypes to the known races of *Pyrenophora tritici-repentis*

Race ^a (ToxA, ToxB, ToxC)	Reported by	Hexaploid genotypes					Tetraploid genotypes		
		Glenlea	6B662	6B365	Katepwa	Salamouni	ND495	Coulter	4B1169
1 (+,-,+)	(Lamari & Bernier, 1989) (Ali & Francl, 2002)	S(N) ^b	R	S(C)	S(N)	R	S(N)	S(N)	R
2 (+,-,-)		S(N)	R	R	S(N)	R	S(N)	S(N)	R
3 (-,-,+)		R	R	S(C)	R	R	R	S(N)	R
4 (-,-,-)		R	R	R	R	R	R	R	R
5 (-,+,-)	(Lamari <i>et al.</i> , 1995) (Ali & Francl, 2002)	R	S(C)	R	S(C)	R	R	S(N)	R
6 (-,+,+)	(Strelkov <i>et al.</i> , 2002) (Ali & Francl, 2002)	R	S(C)	S(C)	S(C)	R	-	S(N)	R
7 (+,+,-)	(Lamari <i>et al.</i> , 2003)	S(N)	S(C)	R	S(N)	R	S(N/C)	S(N)	R
8 (+,+,+)	(Ali & Francl, 2002)	S(N)	S(C)	S(C)	S(N)	R	S(N)	S(N)	R

^aRaces are characterised by their production of three NEs - *Ptr* ToxA, *Ptr* ToxB, and *Ptr* ToxC.

^bS – susceptible; R – resistant; (N) – necrosis; (C) – chlorosis; (N/C) – necrosis and chlorosis; - - symptoms are unknown.

Table 2

Geographic distribution of *P. tritici-repentis* races and their proportion (%) in analysed populations

Country	Race, proportion (%)							
	1	2	3	4	5	6	7	8
USA	40-84	1-4	32	13-32	1	0	0	0
Canada	62-90	36-50	2	0	0	0	0	0
Argentina	2	6	1.5	22	2	2	0	20
Brazil	35	65	0	0	0	0	0	0
Algeria	41	0	0	2	5	4	40	2
Morocco	6	0	0	0	47	44	2	0
Tunisia	0	1	0	1	4	0	49	0
Iran	90	10	0	0	0	0	0	0
Kazakhstan	46-95	5-35	0-23	0	0	0	0	0-34
Azerbaijan	64	3	1	0	13	0	8	11
Kyrgyzstan	100	0	0	0	0	0	0	0
Uzbekistan	100	0	0	0	0	0	0	0
Syria	8	0	58	0	8	0	17	8
Russia	13-23	0-45	0-33	5-61	0	0	0-5	5-13
Finland	19	19	4	10	0	10	0	38
Romania	80	16	2	0	0	0	0	0
Lithuania	48	1	20	5	0	0	0	0
Latvia	90	10	0	0	0	0	0	0

peptide responsible for proper protein folding. Both regions are cut off before synthesizing the final 13.2 kDa (118 amino acid) Ptr ToxA protein (Balance *et al.*, 1996; Ciuffetti *et al.*, 2010; Tomas *et al.*, 1990; Tuori, Wolpert, & Ciuffetti, 1995). Ptr ToxA activity is determined by solvent-exposed loops containing arginyl-glycyl-aspartic acid (RGD) (Sarma *et al.*, 2005). Manning *et al.* (2008) reported that a RGD loop is necessary for Ptr ToxA activity, receptor recognition and internalization. The internalization mechanism of Ptr ToxA is unknown. One of the hypotheses is that Ptr ToxA is uptaken via receptor-mediated endocytosis (Ciuffetti *et al.*, 2014). Chloroplasts are the localization targets of internalized Ptr ToxA, and cell death induced by Ptr ToxA is light-dependent. Ptr ToxA causes the accumulation of reactive oxygen species (ROS), which correlates with the induction of necrosis symptoms. Necrosis is prevented by inhibiting ROS accumulation (Manning *et al.*, 2009; Manning & Ciuffetti, 2005).

Races 5, 6, 7 and 8 produce Ptr ToxB (Lamari *et al.*, 2003; Strelkov *et al.*, 2002). Orolaza, Lamari, and Ballance (1995) were the first who identified Ptr ToxB in culture filtrates of *Ptr*. Ptr ToxB is a small protein of 6.6 kDa mass known to induce chlorosis on sensitive wheat cultivars by a mechanism that affects chlorophyll photooxidation (Strelkov, Lamari, & Ballance, 1998; 1999). Depending on each race and isolate Ptr ToxB coding, *ToxB* is found in multiple

copies varying from 2 to 10 copies (Lamari *et al.*, 2003; Martinez, Oesch, & Ciuffetti, 2004). Copy number of *ToxB* correlates with Ptr ToxB expression level and isolate virulence (Amaike *et al.*, 2008; Strelkov *et al.*, 2002; 2006). *Ptr* race 4 has a single copy of the gene *toxb* that is 86% similar to *ToxB* gene and codes a protein that is 81% similar to Ptr ToxB (Martinez, Oesch, & Ciuffetti, 2004) and is avirulent in Ptr ToxB sensitive wheat genotypes (Figuroa Betts *et al.*, 2011). There is evidence that besides chlorosis induction, Ptr ToxB has additional functions connected to basic pathogenic abilities (Aboukhaddour, Kim, & Strelkov, 2012; Amaike *et al.*, 2008).

Ptr ToxC is produced by races 1, 3, 6 and 8 (Gamba, Lamari, & Brülé-Babel, 1998; Lamari *et al.*, 2003; Strelkov *et al.*, 2002). Ptr ToxC is a non-proteinaceous, low molecular mass, non-ionic, polar molecule (Effertz *et al.*, 2002). Like Ptr ToxB, it can cause chlorosis on susceptible hexaploid wheat genotypes while causing necrosis on susceptible tetraploid wheat lines (Lamari *et al.*, 1995). To date, there are no data about which gene encodes Ptr ToxC production.

Geographic distribution of P. tritici-repentis races

The population of *Ptr* is plastic and adapts to various climatic and agroecological conditions. Studies show that the *Ptr* population varies depending on the geographic location and host diversity (Table

Table 3

The reaction of differential wheat genotypes to the potentially new *P. tritici-repentis* races

Strain (ToxA, ToxB, ToxC)	Reported by	Hexaploid genotypes					Tetraploid genotypes		
		Glenlea	6B662	6B365	Katepwa	Salamouni	ND495	Coulter	4B1169
nc1(-,-,-) ^a	(Ali <i>et al.</i> , 2002)	S(N) ^b	×	S(N)	S(N)	S(N)	S(N)	×	×
SO3(-,-,-)	(Andrie, Pandelova, & Ciuffetti, 2007)	S(N)	R	R	S(N)	R	×	×	×
PT82(+,-,+)		S(N)	S(C)	S(C)	S(C)	R	×	×	×
AR CrossA5 (-,-,+)	(Ali, Gurung, & Adhikari, 2010)	S(N)	R	S(C)	×	R	×	×	×
AR LonB2 (-,-,+)		R	R	S(C)	S(C)	R	×	×	×
Ptr24(-,-,-)	(Benslimane <i>et al.</i> , 2011)	R	R	R	×	R	×	S(N)	R
A029(+,-,-)	(Moreno, Stenglein, & Perelló, 2015)	S(N/C)	R	R	R	R	×	×	×
B028(+,-,-)		R	R	R	R	R	×	×	×
CH007(+,-,-)		S(C)	R	R	S(N)	R	×	×	×
CH009(-,-,-)		R	R	R	R	S(N)	×	×	×
CP021(+,-,-)		S(N/C)	R	R	S(N)	R	×	×	×
CR0819(+,-,+)		R	R	S(C)	R	R	×	×	×
G032(-,-,-)		S(N)	R	R	R	R	×	×	×
G0316(+,-,+)		S(N)	R	S(C)	R	R	×	×	×
G0321(-,-,+)		R	R	S(C)	R	S(C)	×	×	×
G0328(+,-,+)		S(N)	S(C)	S(C)	R	R	×	×	×
G0333(+,-,-)		R	R	R	S(N)	R	×	×	×
H001(+,-,-)		S(N)	S(C)	S(C)	S(N/C)	S(N)	×	×	×
H0014(+,-,-)		S(C)	R	S(C)	R	R	×	×	×
H016(+,-,-)		S(N)	S(C)	S(C)	R	S(C)	×	×	×
25M031(+,-,-)		R	R	R	S(N/C)	R	×	×	×
25M036(+,-,-)		R	R	S(C)	S(N)	R	×	×	×
O0019(+,-,-)		S(N)	S(C)	R	S(N/C)	S(C)	×	×	×
P028(+,-,-)		S(N/C)	S(C)	S(C)	R	R	×	×	×
nc2(-,-,+)	(Abdullah <i>et al.</i> , 2017)	S(N)	R	S(C)	×	R	×	×	×
nc3(-,-,-)		S(N)	R	R	×	R	×	×	×
B16 (-,-,-)	(Guo, Shi, & Liu, 2018)	S(N)	R	R	×	R	S(N)	×	×
T128-1(-,+,-)	(Kamel <i>et al.</i> , 2019)	S(N)	S(C)	R	×	R	×	×	×

^a if the name of the strain is not stated in the publication, then the code nc (not conform) is assigned.

^b S – susceptible; R – resistant; (N) – necrosis; (C) – chlorosis; (N/C) – necrosis and chlorosis; × – symptoms were not investigated;

2). In Canada, races 1 and 2 are predominant in the local *Ptr* population (Aboukhaddour, Turkington, & Strelkov, 2013).

In Argentina, Moreno, Stenglein and Perelló (2015) it was reported that only 54% could be assigned to the eight known races, with races 4 and 8 being the

most widespread. *Ptr* race 2 is predominant in Brazil (Bertagnolli *et al.*, 2019). These findings contradict the earlier report by Ali and Francl (2002), which indicated that race 1 is the most dominant *Ptr* race in South America.

Races 1 and 7 formed most of the Algerian *Ptr* population, while races 4, 5 and 6 were rarely observed. (Benslimane *et al.*, 2011). The situation is similar in Tunisia, where, according to Kamel *et al.* (2019), race 7 is predominant, and races 2, 4 and 5 are in the minority. In Morocco, races 5 and 6 are the most typical representatives of the population (Gamba, Bassi, & Finckh, 2017).

The *Ptr* population in Iran is dominated by race 1 (Momeni *et al.*, 2014). Race 1 also is predominant in Kazakhstan, and in some sites, race 8 was found the second most widespread *Ptr* race (Молдажанова, Мауленбай, & Рсадиев, 2020). Lamari *et al.* (2005) analysed *Ptr* race diversity near the centre of wheat origin – the Fertile Crescent and the Caucasus – and found that the most diverse *Ptr* populations are in Syria and Azerbaijan.

Race 4 is predominant in southern Russia, and race 1 is the most widespread in northern Russia. Races 1, 2, 3 and 4 are commonly seen in the western part of Russia, with no race being distinctively predominant. The *Ptr* population of Finland is dominated by race 8 (Мироненко, Коваленко, & Баранова, 2019).

In Europe and the Baltic states, the diversity of the *Ptr* population is insufficiently studied. Abdullah *et al.* (2017) reported that in Lithuania and Latvia, the most common race is race 1. They also observed that in Romania, similarly to the Baltic states, race 1 is predominant. More detailed research is necessary.

Indications of new P. tritici-repentis races and their geographic distribution

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Some researchers have reported about possible new *Ptr* races with different virulence patterns (Table 3). Ali *et al.* (2002) reported a putative necrotrophic effector that caused extensive chlorosis on the tetraploid wheat line ND495, which is insensitive to *Ptr* ToxC. This NE was similar in size to *Ptr* ToxC, but had distinct chemical properties. Pandelova and Ciuffetti (2005) identified a proteinaceous toxin in the *Ptr* strains lacking *ToxA* gene that induced the same symptoms on the wheat differential set as *Ptr* ToxA. The current race system can describe only eight races, so discovering the new NEs like *Ptr* ToxD, *Ptr* ToxE, etc., and/or new differentials is necessary to incorporate new races in the existing model (Lamari & Strelkov, 2010).

Conclusions

1. Races capable of producing *Ptr* ToxA are predominant in the global *Ptr* population, and possibly this is the result of the selective pressure from cultivars used in modern agriculture.
2. Various researchers worldwide have reported new *Ptr* races, but further research is needed as the key elements necessary for the description of these races have not yet been found.
3. There are many regions where the diversity of the *Ptr* population is not sufficiently investigated, and these knowledge gaps should be filled to gain a better understanding of the global *Ptr* population and wheat-pathogen interaction mechanisms.

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INFLUENCE OF LONG-TERM FERTILIZATION ON YIELD AND QUALITY OF SPRING TRITICALE GRAIN

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Abstract

Triticale (\times *Triticosecale* Wittmack) is a promising cereal crop that has a number of economically valuable properties that are absent in wheat (*Triticum aestivum* L.). The research was conducted at Uman National University of Horticulture (Ukraine) in a long-term stationary experiment, founded in 1964. The aim of the work was to study the influence of long-term application of different fertilizer systems (mineral, organic and organo-mineral) on the yield and grain quality of spring triticale. It has been established that in the conditions of high air temperature and soil moisture deficit, mineral and organo-mineral fertilizer systems have an advantage. In sufficient wet conditions, all studied fertilizer systems are highly efficient. Spring triticale (Kharkiv Hlibodar variety) has a high reaction to fertilizers, as grain yield increases from 6.3–6.6 to 9.0–9.5 t ha⁻¹ ($p \leq 0.05$). Mineral and organo-mineral fertilizer systems have the greatest effect on protein content. In conditions of sufficient moisture, all levels of mineral and organo-mineral fertilizer systems significantly increase the protein content in spring triticale grain. In arid conditions, saturation of crop rotation area with N₉₀P₉₀K₉₀ (M2), N₁₃₅P₁₃₅K₁₃₅ (M3) and Manure 9 t + N₄₆P₆₈K₃₆ (OM2), Manure 13.5 t + N₆₉P₁₀₂K₅₄ (OM3) is preferred. It should be noted that spring triticale is quite reactive with fertilizers, as the protein content increases from 13.2–14.0 to 15.2–16.0% ($p \leq 0.05$) depending on the fertilizer system. The high influence of fertilizer system and year factors on yield and protein content in triticale grain has been established. It should be noted that spring triticale grain yield varies most from the weather conditions of the growing season.

Key words: spring triticale, long-term fertilization, yield, quality.

Introduction

According to Eurostat (FAOSTAT data, 2020 March, available at: <http://www.fao.org/faostat/en/#data/QC>), the gross production of cereals is about 300 million tons per year. Currently, the main crop is soft wheat (*Triticum aestivum* L.) (Kiseleva *et al.*, 2016). However, world production of triticale (\times *Triticosecale* Wittmack) is more than 20 million tons per year, half of which falls on Germany and Poland. Triticale has a number of economically valuable properties that are absent in wheat. They are: fast growth force of green matter, high cold resistance, the higher protein content in grain and average baking properties. Triticale usually grows well under abiotic stress compared to wheat (Furman, 2016). In addition, triticale is characterized by high resistance to major fungal diseases (Liubych *et al.*, 2020). However, the plants are not resistant to *Claviceps purpurea* (Fr.) Tul. (Furman, 2016).

Triticale is a highly productive grain crop. Grain yield can be 7–8 t ha⁻¹ (Liubych, 2019). The crop is highly reactive with fertilizers (Lalević *et al.*, 2019). Triticale grain is used for food and fodder purposes (green fodder, silage, haylage, hay). In addition, it is also an energy crop (Karl, 2017). Triticale grain is a promising raw material for the production of high quality cereal products (Liubych *et al.*, 2020). Triticale flour is used to replace rye (*Oryza sativa* L.) one in the recipe of wheat and rye bread. The soft-grained varieties of triticale are used to make waffles. Triticale flour has no specific properties and recommendations that differ from wheat one (Wrigley & Bushuk, 2017). In addition, the grain of this crop is suitable for the

production of a number of products: cakes, cookies, cupcakes, waffles, noodles and spaghetti (Salmon, Mergoum, & Macpherson, 2004). Therefore, research to increase triticale productivity is relevant.

The use of triticale fertilizers has some features. Fertilizer efficiency also depends on soil type, preceding crop, weather conditions of the growing season, variety potential, etc. (Darguza & Gaile, 2020). Nitrogen in interaction with other elements of mineral nutrition plays a significant role in triticale yield and quality. Plant nutrition with nitrogen has a great influence on the yield and grain quality of triticale (Dekic *et al.*, 2014). To form the high yield and grain quality, it is necessary to provide plants with nitrogen throughout the growing season. However, the use of nitrogen fertilizers, especially high doses, can contribute to environmental pollution, which should be taken into account when developing a fertilizer system for this crop (Nikolic *et al.*, 2012). The research results (Terzic *et al.*, 2018) showed that triticale changes the reaction to intensive nitrogen nutrition in different agroecological conditions. In Serbia, the highest yield was obtained using 120 kg N ha⁻¹, 60 kg P₂O₅ ha⁻¹ and 60 kg K₂O ha⁻¹ for three years of research. In these researches, it was found that triticale grain yield can vary from 2.06 to 4.29 t ha⁻¹ depending on weather conditions. The strong influence of weather conditions on the efficiency of triticale fertilizer was statistically confirmed. However, these researches did not include the use of organic and organo-mineral fertilizers.

Nitrogen fertilizers are one of the biggest factors influencing the formation of grain yield of cereals and its quality (Novak *et al.*, 2019). In researches

(Litke, Gaile, & Ruža, 2017) the use of N120(90+30) and N150(90+60) increased the grain yield of winter wheat from 4.83 to 8.71–9.11 t ha⁻¹ per cultivation after winter rape. Increasing the dose of nitrogen fertilizers to N180–240 did not significantly increase this indicator. The efficiency of winter wheat fertilization in the experiment varied from other elements of agricultural technology. However, the research did not include the study of grain productivity formation in the field crop rotation with long-term fertilization, which does not allow to determine crop reaction to the level of soil fertility. In addition, the study was conducted with winter wheat, the fertilizer of which differs from spring triticale.

Researches by other scientists have shown high efficiency of nitrogen fertilizers in spring triticale cultivation. However, studies were performed with the forage variety, so the optimal dose was the use of N₅₆ (Obour, Holman, & Schlegel, 2020). Given the insufficient study of spring triticale reaction at the soil fertility level of podzolic chernozem, created by long-term use of fertilizers in the field crop rotation, research is relevant.

The aim of the work was to study the influence of the long-term application of different fertilizer systems (mineral, organic and organo-mineral) on the yield and grain quality of spring triticale.

Materials and Methods

The research was performed in the field conditions of Uman National University of Horticulture during 2007–2009 in the stationary experiment of the Department of Agrochemistry and Soil Science. The experiment was launched in 1964, and it is based on a 10-field crop rotation extended in time and space (spring triticale + meadow clover (*Trifolium pretense* L.), meadow clover, winter wheat, sugar beet (*Beta vulgaris* L. *saccharifera*), maize (*Zea mays* L.), peas (*Pisum sativum* L.), winter wheat, silage maize, winter wheat, sugar beet). The efficiency of fertilizer systems was studied on 10 backgrounds (average saturation of crop rotation area with fertilizers) – without fertilizers (control), N₄₅P₄₅K₄₅ (M1), N₉₀P₉₀K₉₀ (M2), N₁₃₅P₁₃₅K₁₃₅ (M3), Manure 9 t (O1), Manure 13.5 t (O2), Manure 18 t (O3), Manure 4.5 t+N₂₃P₃₄K₁₈ (OM1), Manure 9 t+N₄₆P₆₈K₃₆ (OM2), Manure 13.5 t+N₆₉P₁₀₂K₅₄ (OM3). Fertiliser rates were applied in the form of half-rotted cattle straw manure, ammonium nitrate, granulated

superphosphate, mixed potassium salt and potassium chloride. The total area of the plot was 180 m², the experimental plot covered 100 m², the experiment was repeated three times on the same location. ‘Kharkiv Hlibodar’ spring triticale variety was used in the experiment.

The experimental plot was located in Mankivka natural-and-agricultural district of the Middle-Dnieper-Buh district of the Forest-Steppe Right-Bank province of the Forest-Steppe zone with geographical coordinates of 48° 46’56,47” of north latitude and 30° 14’48,51” of east longitude by Greenwich. Height above sea level was 245 m. The soil of the experimental field was podzolized chernozem. Before the experiment the soil was under a long-term cultivation under field crops. Soil samples taken before the experiment (1964) had the following parameters: content of physical clay – 66.5%, base saturation – 95%, humus content – 3.31%; content of easily hydrolysable organic nitrogen (according to the Tjurin-Kononova method); mobile compounds of phosphorus and potassium (according to Chirikov method) – 122 and 135 mg kg⁻¹ respectively; pH_{KCl} – 6.2. Soil was characterized by such indicators at the time of setting up the experiment.

The protein content was determined by the method of infrared spectroscopy using Infratek 1241. Statistical data processing was performed using STATISTICA 10. Interpretation of the influence level by partial coefficient (thumb rule – Cohen): 0.02–0.13 – weak, 0.13–0.26 – medium, ≥0.26 – high. The null hypothesis was confirmed or refuted during the performing of variance analysis. The p-value was determined for this purpose, which showed the probability of the corresponding hypothesis. In cases, where p<0.05, ‘the null hypothesis’ was refuted and the influence of the factor was significant.

The timing of sowing and harvesting of spring triticale varied depending on weather conditions (Table 1). The higher air temperature in 2007 contributed to the earlier sowing and harvesting of spring triticale. In 2008 and 2009, sowing and harvesting were typical for the Right-Bank forest-steppe zone.

The characteristic feature of 2007 (Table 2) was the increase in air temperature, low rainfall and drought, which lasted from May to July. Thus, during April-July period, only 92.9 mm of precipitation fell, which is 3.4 times less than the long-term average.

Table 1

Spring triticale sowing and harvesting time date in spring during trial years

Indicators	Year of research		
	2007	2008	2009
Sowing time	March 17 th	March 29 th	April 7 th
Harvesting time	June 30 th	July 22 th	July 19 th

Table 2

Weather conditions at the experimental site

Month	Year							
	2007	2008	2009	1961–1990	2007	2008	2009	1961–1990
	Precipitation (mm)				Temperature (°C)			
March	12.8	49.6	46.8	39.0	5.5	4.6	2.2	0.4
April	10.0	54.5	0.0	48.0	8.5	10.0	10.1	8.5
May	6.5	33.7	38.5	55.0	18.4	13.9	14.6	14.6
June	35.3	51.2	49.0	87.0	20.9	18.6	20.2	17.6
July	28.3	44.7	86.1	87.0	23.0	21.1	21.2	19.0

This resulted in the lowest yield of spring triticale. Weather conditions in 2008 were more favourable for the growth and development of spring triticale although during the growing season 233.7 mm of precipitation fell, which is 1.4 times less than the average long-term amount. Weather conditions in 2009 were characterized by uneven distribution of precipitation during the spring triticale vegetation and a slow increase in heat at the beginning of the growing season. April was dry and warm, the moisture in a meter layer of soil was enough to get even sprouts. In general, weather conditions contributed to the high yield of spring triticale although 220.4 mm of precipitation fell in April–July, which is 1.4 times less than the long-term average.

Characteristics of Kharkiv Khllobodar spring triticale variety. Applicant and owner is V. Ya Yuryev Institute of Plant Breeding. The variety is hexaploid. The type of development is spring. Anthocyanin colour of the seedlings is medium. The bush is semi-straight. The stem is medium-sized with very strong pubescence near the ear. The ear is white, long, of medium density. The awns are long, located along the entire length of the ear. The kernel is red, large. Weight of 1000 grains is 40.0 g. Plants are 114–117 cm high. It is medium-ripe, ripens for 96–97 days. Variety lodging resistance is 7.6 points, drought resistance is 8.0 points. The variety is weakly affected by powdery mildew, brown rust and root rot. It is recommended for the Forest-Steppe and Polissia of Ukraine.

Results and Discussion

The research results show that all fertilizer systems significantly increased the yield of spring triticale grain compared to the variant without fertilizers ($p \leq 0.05$) (Figure 1). The lowest fertilizer efficiency was established in 2007. Thus, the grain yield of spring triticale under the mineral fertilizer system increased by 1.3–1.7 times (2.7–3.5 t ha⁻¹), and that of the organic system by 1.1–1.2 (2.4– 2.6 t ha⁻¹), organo-mineral system – 1.2–1.6 times (2.6–3.3 t ha⁻¹)

depending on the level of crop rotation saturation with fertilizers. In 2008, this indicator increased by 1.2–1.5 times (7.7–9.5 t ha⁻¹) depending on the fertilizer system and the level of crop rotation area saturation. A similar tendency in the formation of the spring triticale crop was established in 2009.

It should be noted that in the best years in terms of precipitation distribution, the variants of the mineral and organo-mineral fertilizer systems significantly increased the grain yield between the levels of crop rotation area saturation. The application of manure in field crop rotation had different efficiency. Thus, the average saturation of crop rotation area with manure at a dose of 13.5 t ha⁻¹ (O2) and 18.0 t ha⁻¹ (O3) did not significantly affect the grain yield of spring triticale compared to Manure 9 t ha⁻¹ (O1) variant in 2007. In 2008, the variant with average manure saturation at a dose of 13.5 t ha⁻¹ was significantly higher in yield compared to a single dose. In 2009, even the saturation of 18.0 t ha⁻¹ with manure significantly increased compared to the Manure 13.5 t ha⁻¹ variant.

In conditions of moisture deficiency, the efficiency of mineral and organo-mineral fertilizers is higher compared to the organic system. In years with the best distribution of precipitation, the efficiency of the mineral and organo-mineral fertilizer system is the same. The efficiency of the organic fertilizer system is not stable: in 2008, the yield was significantly lower than in other fertilizer systems, and in 2009 it was at their level.

The effect of long-term application of fertilizers in field crop rotation on spring triticale grain yield was different depending on weather conditions. In the dry year of 2007, this indicator was the lowest. It should be noted that the organic system was less efficient as a result of deteriorating conditions of soil organic matter mineralization. The formation of significantly lower yield of spring triticale in the organic system in 2008 is due to the use of nutrients from the previous crop. In 2009, this phenomenon did not exist, so grain yield was at the level of other fertilizer systems. The

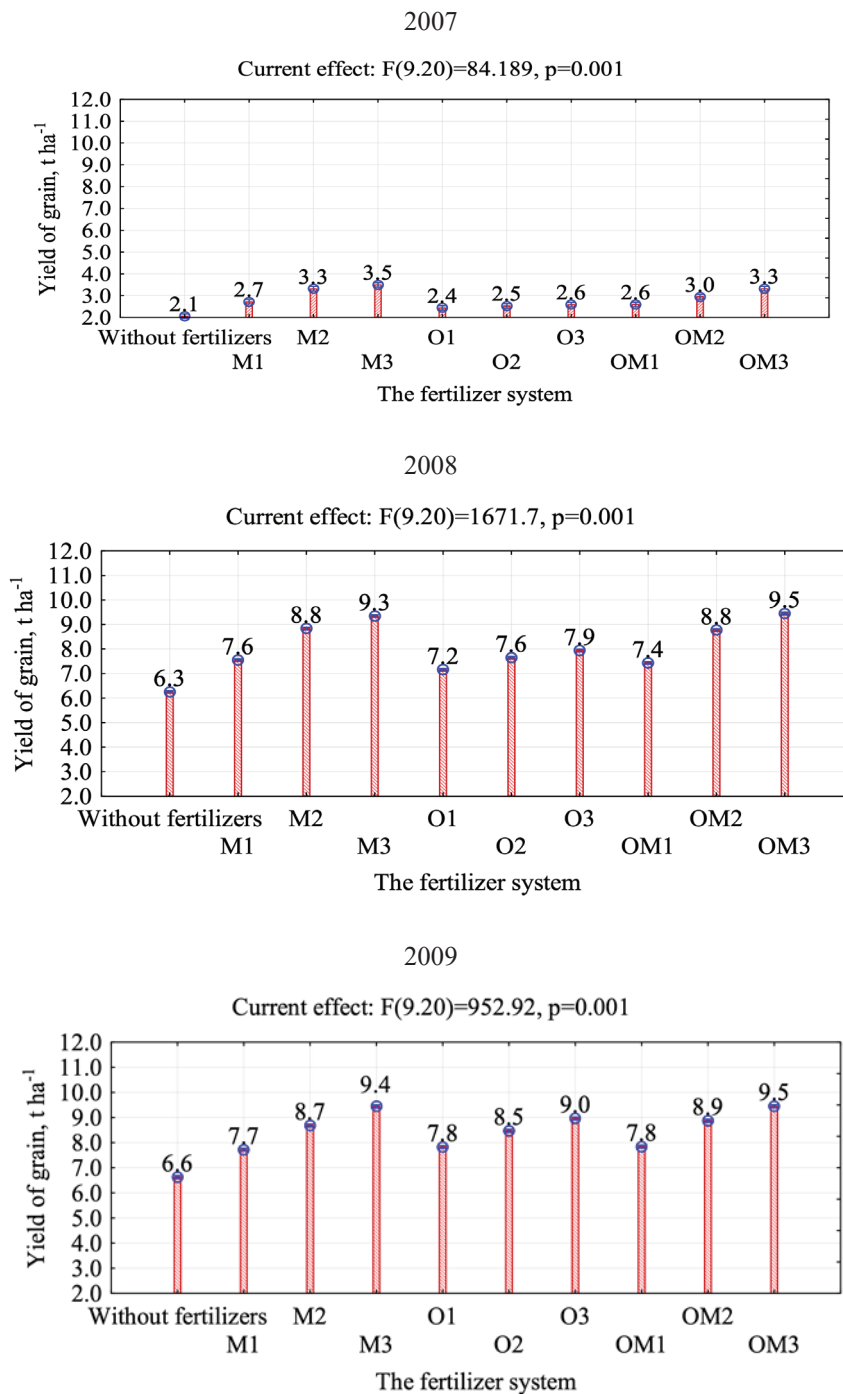


Figure 1. Spring triticale grain yield depending on fertilizer and trial year, t ha⁻¹: Without fertilizer – control; M1 – N₄₅P₄₅K₄₅, M2 – N₉₀P₉₀K₉₀, M3 – N₁₃₅P₁₃₅K₁₃₅, O1 – Manure 9 t, O2 – Manure 13.5 t, O3 – Manure 18 t, OM1 – Manure 4.5 t+N₂₃P₃₄K₁₈, OM2 – Manure 9 t+N₄₆P₆₈K₃₆, OM3 – Manure 13.5 t+N₆₉P₁₀₂K₅₄.

obtained tendencies are similar to the results given in the works of other scientists. Thus, in the long-term field experiment, the effectiveness of fertilization for winter wheat significantly changed depending on the precursor and fertilizer system. Scientists statistically obtained a higher yield for the application of N₁₃₅P₃₀K₁₀₀+5 t ha⁻¹ organic fertilizer – 7.15 t ha⁻¹. The use of N₁₃₅P₃₀K₁₀₀ increased this indicator to only

6.65 t ha⁻¹ for cultivation after pea precursor. The use of such a fertilization system of winter wheat for growing after the winter barley precursor, grain yield was significantly lower than pea precursor. The yield also varied with the weather conditions of the study year. Thus, this indicator varied from 5.98 to 8.29 t ha⁻¹ for cultivation after pea and from 4.94 to 6.93 t ha⁻¹ – after winter barley. It should be noted that the share of

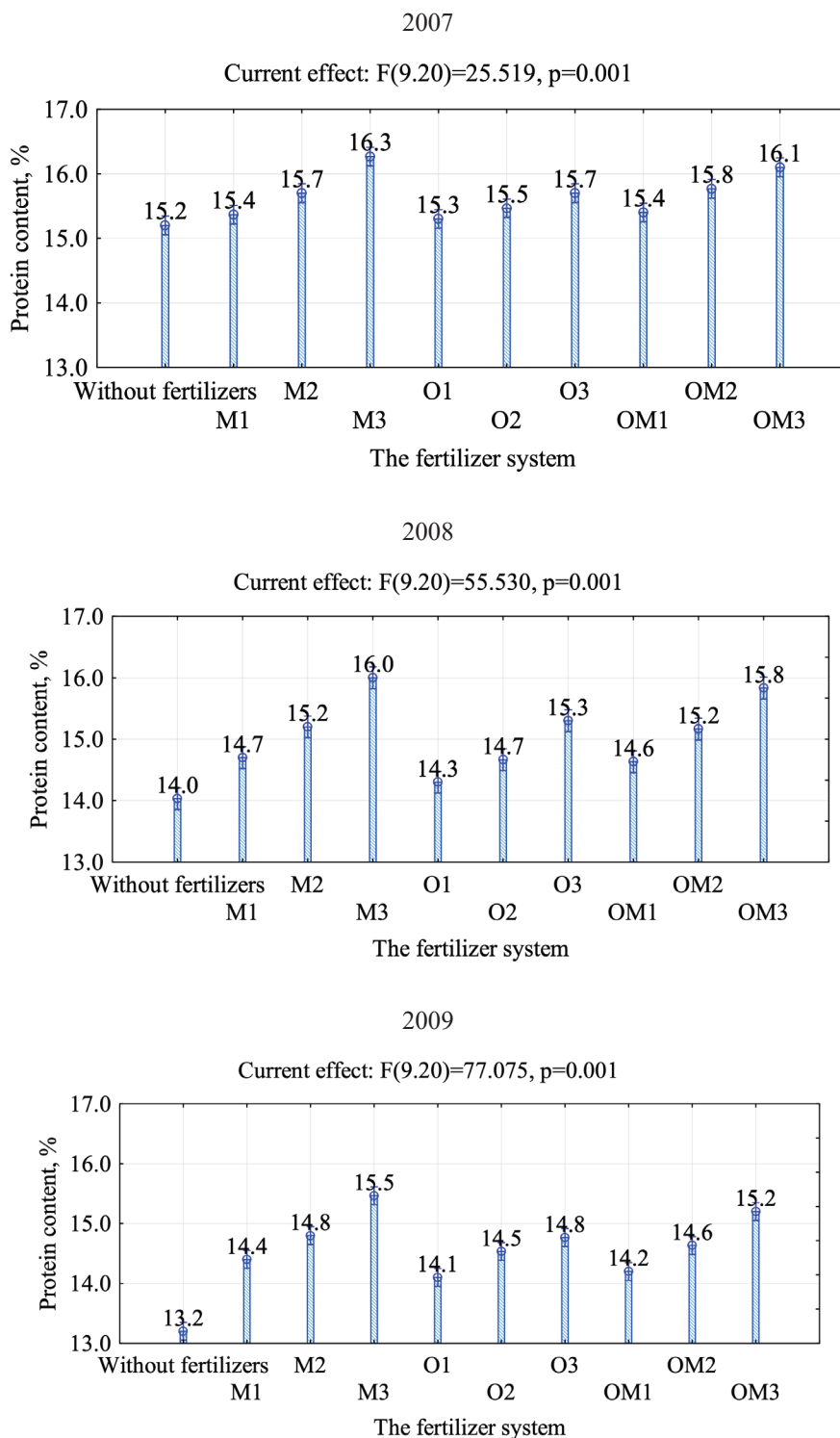


Figure 2. Protein content in spring triticale grain depending on the fertilizer and trial year, %: Without fertilizer – control; M1 – $N_{45}P_{45}K_{45}$, M2 – $N_{90}P_{90}K_{90}$, M3 – $N_{135}P_{135}K_{135}$, O1 – Manure 9 t, O2 – Manure 13.5 t, O3 – Manure 18 t, OM1 – Manure 4.5 t + $N_{23}P_{34}K_{18}$, OM2 – Manure 9 t + $N_{46}P_{68}K_{36}$, OM3 – Manure 13.5 t + $N_{69}P_{102}K_{54}$.

cereals in field crop rotation did not affect the efficiency of fertilizer (Babulicova, 2014; Terzic *et al.*, 2018).

Different fertilizer systems in the field crop rotation had different effects on the protein content of spring triticale grain (Figure 2).

Thus, in 2007 this indicator was significantly affected by crop rotation saturation of $N_{90}P_{90}K_{90}$ (M2), $N_{135}P_{135}K_{135}$ (M3) and Manure 9 t + $N_{46}P_{68}K_{36}$ (OM2), Manure 13.5 t + $N_{69}P_{102}K_{54}$ (OM3), as well as the variant with the highest manure saturation (O3).

The protein content in these variants increased by 3–7% compared to areas without fertilizers. In 2008, all levels of crop rotation saturation with mineral and organo-mineral fertilizers significantly increased the protein content. It should be noted that the highest (15.8–16.0%) indicator was in $N_{135}P_{135}K_{135}$ (M3) and Manure 13.5 t + $N_{69}P_{102}K_{54}$ (OM3) variants. Under the organic fertilizer system, the protein content significantly increased by 4–9% at the second and third levels of manure saturation. In 2009, all levels of saturation and fertilizer systems in the field crop rotation significantly increased the protein content in grain. However, the mineral and organo-mineral fertilizer system had the greatest effect. Thus, the protein content increased by 9–17% for the mineral, by 8–15% for the organo-mineral and by 7–12% for the organic fertilizer system.

The research results show that the improvement of mineral nutrition, especially nitrogen one, contributes to increase the grain protein content. Researches by scientists (Jaśkiewicz & Szczepanek, 2018) confirm this pattern. In addition, they note a significant effect of weather conditions of the growing season (precipitation and air temperature) on the content of nitrogen-containing compounds in the grain. The fall of more precipitation in 2008–2009, provided that the mineral nutrition of spring triticale plants improved, contributed to an increase in grain yield with an increase in protein content. This tendency was found in their researches by scientists studying the features of nitrogen nutrition of different triticale varieties (Lalević *et al.*, 2019).

Spring triticale cultivation with long-term saturation of crop rotation with mineral fertilizers is environmentally safe, as confirmed by previous researches (Hospodarenko *et al.*, 2019). The obtained research results can be used for the spring triticale variety ‘Kharkiv Hlibodar’ or varieties of this type. In addition, it can be grown on soils with medium and high fertility, as it has a high reaction to it. For other varieties or types of crop rotation it is necessary to conduct separate researches.

The organic fertilizer system had less effect on the protein content, as manure nutrients were first used by sugar beet plants and then by spring triticale. In addition, the nutrients were in organic form. During

the heading growth stage – grain maturation, this process was weakened by the lack of moisture in the upper soil layer and high temperature. Statistically significant ($p \leq 0.05$) studied factors (fertilizer system, year) influenced the formation of yield and protein content in spring triticale grain. The power of effect was high for both factors. However, the formation of spring triticale grain yield was most influenced by the factor of the year, and less by the fertilizer system. The effect of these factors on the protein content was almost the same. This indicates that the effectiveness of spring triticale fertilizer depends on the weather conditions of the growing season. The protein content in the grain of spring triticale under such conditions varies less from weather conditions.

Conclusions

The long-term use of fertilizers in the field crop rotation under mineral, organic and organo-mineral systems significantly influenced the formation of spring triticale crop. In conditions of high air temperature and lack of soil moisture, mineral and organo-mineral fertilizer systems are preferred. In conditions with sufficient rainfall, all studied fertilizer systems are highly efficient. Spring triticale variety ‘Kharkiv Hlibodar’ has the high reaction to fertilizers, as grain yield increases from 6.3–6.6 (control) to 9.0–9.5 t ha⁻¹ ($p \leq 0.05$). Mineral and organo-mineral fertilizer systems have the greatest effect on protein content. In conditions of sufficient moisture, all levels of the mineral and organo-mineral fertilizer systems significantly increase the protein content in spring triticale grain. In arid conditions, saturation of crop rotation area of $N_{90}P_{90}K_{90}$ (M2), $N_{135}P_{135}K_{135}$ (M3) and Manure 9 t + $N_{46}P_{68}K_{36}$ (OM2), Manure 13.5 t + $N_{69}P_{102}K_{54}$ (OM3) is preferred. The organic fertilizer system has less effect on this indicator. It should be noted that spring triticale is well reactive with fertilizers, as the protein content increases from 13.2–14.0 to 15.2–16.0% ($p \leq 0.05$) depending on the fertilizer system. The high effect of fertilizer system and year factors on yield and protein content in triticale grain was established. It should be noted that the grain yield of spring triticale varies most from the weather conditions of the growing season.

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DIET OPTIMIZATION FOR DAIRY COWS TO REDUCE AMMONIA EMISSIONS

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Abstract

Feeding livestock a balanced diet with a differentiated crude protein (CP) content, depending on the lactation phase, can reduce nitrogen emissions from livestock excrement and urine. A higher content of non-starch polysaccharides in livestock diets improves feed absorption in the livestock body and, consequently, nitrogen is emitted more from protein present in livestock manure than from urea acid present in livestock urine. The aim of the study is to calculate the ammonia emission reduction potential in Latvia by optimizing the feeding of dairy cows and ensuring life longevity, as well as provide justification for ammonia emission reduction in dairy farms. Calculations made by using the NorFor Model for optimization of dairy cow (*Bos primigenius f. taurus*) diets revealed that compared with low-yielding cows, a higher CP content diet fed to high-yielding cows at the beginning of lactation increased the amount of nitrogen (N) in their excrement and urine by 90–180 g d⁻¹. Reducing the CP content in the cow diet by an average of 10 g kg⁻¹ dry matter (DM) during mid-lactation resulted in the same trend. Reducing the CP content in the cow diet during late lactation and the dry period by another 20–30 g kg⁻¹ of DM, N emissions from excrement and urine significantly decreased. Increasing the lifespan of dairy cows also means reducing ammonia emissions from the farm. By increasing the number of lactations per cow on dairy farm, it is possible to reduce the number of heifers per cow. The total reduction of ammonia emissions in Latvia was calculated based on a long-term projection of a decrease of 0.1 heifer per dairy cow. Ammonia emissions could be reduced by 0.051 kt by decreasing the number of heifers by 12.54 thou. at the planned increase in the lifespan of dairy cows by 2030.

Key words: crude protein, stage of lactation, climate policy.

Introduction

In 2018, the agricultural sector accounted for 12.83 kt (83.0%) of total (15.46 kt) ammonia emissions in Latvia and was the largest contributor to ammonia emissions in the country (Latvia's Informative Inventory..., 2020). An air pollutant inventory report lists ammonia emissions from:

- management of manure from cattle (*Bos primigenius taurus*), sheep (*Ovis aries*), goats (*Capra aegagrus hircus*), horses (*Equus ferus caballus*), pigs (*Sus scrofa domesticus*), poultry and fur animals, accounting for 51% of the total emissions;
- agricultural soils, including the application of nitrogen fertilizers, manure, sewage sludge or other organic fertilizers and the deposition of urine and manure on pastures, as well as from crop production (Latvia's Informative Inventory..., 2020).

In 2015, compared with the base year 2014, ammonia emissions from the agricultural sector decreased by 0.89 kt or 6.4%, while in 2016 compared with 2015, the emissions increased by 0.08 kt or 0.6%, but in 2017 compared with 2016, the emissions increased by 0.25 kt or 1.9%. A larger decrease of emissions was in 2018 compared with the base year by 1.15 kt or 8.2%. The decrease in ammonia emissions could be explained by a decrease in the number of livestock, especially dairy cows, from 165.9 thou. in 2014 to 144.5 thou. in 2018. Dairy farming is one of the most important agricultural

industries in Latvia. The number of dairy cows was relatively steady, yet it tended to decrease in recent years. In the period 2014–2018, the number of cattle decreased by 5.2 thou. or 2.0%, while the number of dairy cows decreased by 21.4 thou. or 12.9%. As the number of livestock decreased, ammonia emissions from manure management also tended to decrease, while the emissions from crop production and the application of fertilizers (including livestock manure and slurry) had mixed trends. Although the amount of ammonia emissions from manure management decreased, the decrease is insufficient to meet the target set for Latvia to reduce ammonia emissions to 14.44 kt in 2030, which would be 1% less than in 2005. Without controlling economic activity in agriculture and implementing no measures for reducing ammonia emissions, the emissions from agriculture in Latvia in 2030 are projected to account for approximately 89% of total ammonia emissions, and the projected total ammonia emissions will be 8.6% more than in 2016 and 18.5% more than in 2005. Therefore, the Air Pollution Reduction Action Plan of Latvia for 2020–2030 envisages additional measures to achieve the ammonia emission reduction target¹. Research studies around the world report different ammonia emissions per cow in the range of 3.8–21.0 g d⁻¹ for cows that graze or are fed balanced alfalfa (*Medicago sativa L.*) and maize (*Zea mays*) silage diets. The mentioned per cow emissions were lower than those from cows kept in free-stall housing facilities and not grazed, with an average of 109 g of ammonia d⁻¹ per cow

¹ On the Air Pollution Reduction Action Plan of Latvia for 2020–2030. Cabinet decree No. 197 (2020). <https://likumi.lv/ta/id/314078-par-gaisa-piesarnojuma-samazinasanas-ricibas-planu-2020-2030-gadam>

reported during manure trench cleaning. The forage-to-concentrate (F:C) ratio in the diet make some effect on gas emissions from manure. Study results of M.J. Aguerre *et al.* suggest that within the 47:53 to 68:32 dietary F:C ratio, dietary treatment effects on enteric CH₄ production had no effect during storage and had no effect on ammonia, nitrous oxide, methane and carbon dioxide emission rates from stored manure, but changes in fermentation pattern could contribute to reduction in emissions in the long term (Aguerre, Wattiaux, & Powell, 2012; Hristov *et al.*, 2013). The goal of dietary planning for dairy cows is to reduce ammonia emissions from cow housing facilities, manure storage facilities and manure application to field. It is more difficult to plan diets for dairy cows during the grazing period, yet ammonia emissions from cows grazing on pasture are relatively lower than those from the cows kept in housing facilities. Dietary planning involves: a) feeding a diet to cows, depending on their age and lactation phase; b) reducing the crude protein (CP) content of the diet with or without the addition of certain amino acids and indigestible proteins; c) increasing the content of non-starch polysaccharides in the diet, which leads to higher nitrogen emissions from CP present in manure than from urea/uric acid present in urine. Young and highly productive livestock need diets with a higher CP content than older, low-productivity livestock. Reducing the average CP content of the diet by 10 g per kilogram of dry matter (i.e., by 1%), the total ammonia emissions from all nitrogen emission sources on the farm decrease by approximately 10% (Bittman *et al.*, 2014). According to the United Nations (UN) guidelines for ammonia emission reduction on mixed livestock farms, 10–40% of the nitrogen surplus relates to ammonia emissions. European agriculture produces on average 94% of total ammonia emissions. Research studies have found that ammonia emissions range from 5.1 to 13.6 g per kilogram of energetically corrected milk (ECM). Northern European farms produced on average 36% less ($P < 0.001$) ammonia emissions than US farms did, yet energy consumption ranged from 2.45 to 3.81 MJ kg⁻¹ ECM or on average 19% more than on US farms. The lower ammonia emissions could be explained by lower air temperatures, a lower CP content in livestock diets, and an earlier application of manure to cropland, as well as on average 16% lower milk production per cow compared with US farms. A number of research studies by scientists in Europe and around the world have found that it is possible to reduce both ammonia and other greenhouse gas (GHG) emissions by introducing precision feeding and optimizing CP in diet and energy intake in dairy cows, prolonging their productive life and improving their health (Aguerre, Wattiaux, & Powell, 2012; Hristov *et al.*, 2013; Powell & Rotz, 2015). Small and

medium farms, as well as organic farms, often do not follow recommendations on feeding cows, and this could lead to metabolic diseases as well as higher GHG emissions from the cows.

The research aim is to estimate the potential for ammonia emission reduction in Latvia if optimizing feed intake in dairy cows and prolonging their lifespan, based on 2019 data from the national Agricultural Data Centre (ADC) for the dairy industry, as well as provide justification for ammonia emission reduction on farms.

Materials and Methods

The research used the Latvia ADC database (Dzīvnieku reģistrs, 2020) on dairy cow productivity and housing and feeding technologies in 2019 to obtain data for analysis. To reduce ammonia emissions by optimizing feed intake in dairy cows, two measures were selected: 1) optimizing the content of crude protein, sugars and non-starch polysaccharides (cellulose, hemicellulose) in the diet for dairy cows with the aim of increasing productivity and reducing GHG and ammonia emissions, and 2) feeding a diet to cows, depending on their lactation phase, productivity and age with the aim of reducing ammonia emissions.

To reduce an increase in N emissions, recommendations have been developed for optimizing feed intake in dairy cows, depending on their productivity, lactation phase and physiological condition. The research employed the NorFor Model for optimization of dairy cow diets with the aim of reducing the CP content of the diet and balancing the energy level of the diet, which allows reducing N emissions (Nordic Feed Evaluation System, 2020).

To balance the diet, feed optimization settings included: an energy balance, metabolizable protein, a protein balance, fatty acids, the fill value of the diet, the chewing time index, etc. The diet included feedstuffs based on previous research on the types and proportions of feedstuffs fed to various dairy herds in Latvia (Degola *et al.*, 2016). The NorFor Model employed by the research was supplemented with a climate module that incorporates GHG emissions from animal and feed production. The crude protein content of the diet (g kg⁻¹ DM), N in excrement and urine (g d⁻¹), methane (MJ kg⁻¹ ECM), planned milk yield (ECM, kg d⁻¹) and milk production per kg of dry matter (kg kg⁻¹ DM) were calculated based on data on a balanced diet and the average milk yield in Latvia in 2019 on conventional dairy farms of various sizes (Table 1). The data on the number of cows, their productivity, stage of lactation and housing conditions were obtained from the ADC database. The ADC database has data on a total of 4121 dairy farms.

For designing a livestock diet, the chemical composition of feedstuffs is borrowed from the feed

Table 1

Distribution of selected conventional dairy farms by size, milk yield and feed in Latvia, 2019

Farm category	Average number of dairy cows per farm	Average milk yield, kg per cow per year	Feedstuffs included in diet
Small farms	≤ 10	6273	grass silage, hay, ground barley, beans, molasses
Medium farms	11 – 300	6843	grass silage, hay, ground barley, beans, molasses
Large, industrial-scale farms	> 301	10132	grass silage, hay, ground barley, beans, molasses, corn silage, rapeseed cake, soybean meal

catalogue that lists average quality parameters of feedstuffs available in Latvia (Lopbarības analīžu ..., 2013).

Given the research by scientists from various countries (Aguerre *et al.*, 2012; Bittman *et al.*, 2014; Powell *et al.*, 2014) on the possibilities of reducing ammonia emissions by decreasing the CP content in the diet, the present research differentiated the level of CP in the diet according to the stages of lactation, providing a 15–16% crude protein intake during early lactation (<60 days in milk (DIM)), 13–14% during mid-lactation (60–280 DIM) and 12–13% during late lactation (>280 DIM) and the dry period, depending on the feedstuffs and their quality. Decreasing the CP content in the diet in this way ensures a milk yield in alignment with cow productivity during lactation.

To calculate the potential for ammonia emission reduction, the research employed the IPCC (Intergovernmental Panel on Climate Change) methodology for calculating ammonia emission inventories, which is also used by internationally audited national inventory reports of Latvia, as well as the official agricultural projections reported (The Intergovernmental Panel ..., 2021). Emission reduction potential is a term widely used in scientific discussion and is usually applied to a GHG or ammonia emission reduction effect (potential) of a management practice over a period of time, which is usually aligned with the policy planning period. In addition, for the reliability of the results, the projection period is chosen to be as short as possible owing to technological progress, changes in policy priorities, changes in market conditions, etc. The research chose a projection period until 2030 and estimated a potential ammonia emission reduction for the period if dietary planning were introduced as a deliberate management measure. Such calculations can identify technical potential (achievable by means of current technologies), economic potential (achievable in a cost-effective way) or political potential (agreed by policy makers). The present research calculated the technical potential because dietary planning is applicable to the dairy cows (projection for a period until 2030) to which, according to experts, it was not been applicable so far.

Results and Discussion

Nitrogen use efficiency.

The basic assumption in nitrogen management is that reducing a nitrogen surplus (N surplus) and increasing NUE can contribute to reducing ammonia emissions. According to A.N. Hristov, W.J. Price & B. Shafi (2005), ruminants are relatively inefficient users of nutritional nitrogen (N), as only 25% of nutritional N is absorbed by them for milk protein production, the remaining N is excreted through excrement and urine. Urine urea nitrogen (UUN) excreted through dairy cow urine is the one of sources of nitrogen emissions from manure. Milk urea nitrogen (MUN) is an indicator of the efficiency of absorption of nutritional nitrogen used to assess the cow diet and to monitor and ensure the intake of nitrogen by dairy cows. Between 51% and 84% of UUN is emitted as ammonia, and the lowest N losses are incurred on pastures, as urine is rapidly absorbed by soil, while the highest N losses are incurred on farms with tied housing. A MUN reduction by 1 mg dL⁻¹ (in the range of 16–10 mg dL⁻¹) could lead to a 7% reduction in ammonia and nitrous oxide emissions from excrement. An optimal diet for dairy cows makes it possible to reduce the amount of MUN in milk from 12–10 mg dL⁻¹, achieving a total reduction of ammonia emissions by 35–42% and nitrogen oxide emissions by 18–21%. A MUN amount of 10 mg dL⁻¹ indicates a sufficient supply of CP in the diet for achieving high milk yields. UUN losses in the form of ammonia range from 40% on pasture farms to 84% on non-pasture farms. To achieve a MUN reduction by 1 mg dL⁻¹, the CP content of the diet must be reduced by about 6 g kg⁻¹ of dry matter (Powell, Wattiaux, & Rotz, 2014). It is concluded that grazing dairy cows with high milk yield leads to high NUE in the range of 0.3–0.5 kg kg⁻¹, low stocking density and low N surplus in the range of 100–150 kg N ha⁻¹ a year in comparing with other farming systems. On the mixed crop and dairy farms with high milk yields by feeding concentrates to cows NUE is in the range of 0.4–0.6 kg kg⁻¹; N surplus is in the range of 50–150 kg N ha⁻¹ a year. On dairy farms having not enough arable land, N-output through milk, cows and manure is approximately equal to N-input; a N surplus

is the loss of ammonia and other N compounds from cow housing facilities and manure storage facilities, and NUE is high in the range of 0.8–0.9 kg kg⁻¹ (Bittman *et al.*, 2014). Feed nitrogen use efficiency is generally higher on dairy farms using the non-grazing system (26–33%) than those using the grazing system (16–24%). The research found that a 1% reduction in the CP content of the diet did not affect milk production, but increased nitrogen use efficiency by 2% and reduced N emissions from excrement and urine by 32 and 28 g N per cow per day that reduced N losses (Powell & Rotz, 2015). Nitrogen balance research has found that on typical dairy farms, only 12 to 36% N is removed with products intended for sale, while about 70% is lost mainly through evaporation and leaching (Spears, Kohn, & Young, 2003). An excessive addition of N to dairy cow diets can adversely affect their productivity, nutrient absorption efficiency in milk production, reproductive performance, economic performance, the environment and public awareness of dairy farming.

Effects of dairy cow age on emissions

It is easier to introduce differentiated diets for dairy cows kept under free-stall housing, as it is possible to group the cows according to their productivity and stage of lactation. On the small and medium farms where animals are grazed, cows achieve a longer lifespan. For example, on organic dairy farms in 2019, the average lifespan of cows was 4.29 lactations with an average milk yield of 5873 kg per year, on large conventional dairy farms with more than 300 dairy cows it was 3.00 lactations with an average milk yield of 10132 kg, while on medium conventional dairy farms it was 3.70 lactations with an average milk yield of 6843 kg (Table 2).

Most dairy cows (57%) are farmed by conventional farms with 11–300 cows, which have the largest feasible to increase the average number of lactations to 4.5. On such dairy farms, agricultural production is less intensive, the cows are grazed during summer, and

their average productivity is relatively lower than that on intensive farms, which have 4 lactations per cow. On organic and home farms, which represent 15% of the total number of dairy cows in Latvia, the number of lactations is in the range of 4.3–4.5. By improving cow welfare and diets on such farms, it is possible to reach at least 5 lactations per cow. By increasing the number of lactations per cow in all types of farms, it is possible to reduce the number of heifers per dairy cow. The total reduction of ammonia emissions in Latvia was calculated based on a projection of a decrease of 0.1 heifer per dairy cow. According to a long-term projection, ammonia emissions could be reduced by 0.051 kt by decreasing the number of new heifers by 12.54 thou. at the planned increase in the lifespan of dairy cows by 2030.

Achieving this goal by dairy farms requires regularly ensuring livestock welfare across all groups of livestock, designing and implementing optimized for dairy cows, analysing changes in the number of lactations, productivity and reproduction rates (including the number of inseminations) and implementing measures to optimize the performance of dairy cows. Grazing, including the extension of the grazing period, is a factor contributing to livestock health. The mentioned farming approaches could only be implemented over a longer period. Several scientists have pointed out that such strategies can make a positive effect on livestock welfare and are likely to reduce methane (CH₄) emissions from the fermentation process in the cow intestinal tract, especially if expressed as emissions per unit of milk produced (Kebreab *et al.*, 2001; Powell, Rotz, & Weaver, 2009).

Optimizing crude protein intake in dairy cows, depending on their productivity and stage of lactation

Dairy cow productivity particularly depends on the fodder fed, the size of the farm, the type of housing and other external environmental factors. Compared with low-yielding cows, high-yielding cows consume

Table 2

Characteristics of dairy cows on selected dairy farms in Latvia in 2019

Farm category	Cows, 365 days		Farm		Average milk yield, kg	Number of lactations	
	number	percentage	number	percentage		average	target in research
Organic, total	16139	100	849	100	5873	4.29	5.0
Conventional, total	101740	100	3181	100	6602	3.50	4.0
including small (1–10 cows)	9475	9.3	1628	51.2	6273	4.40	5.0
medium (11–300 cows)	63472	62.4	1503	47.2	6843	3.70	4.5
large (≥301 cows)	28793	28.3	50	1.6	10132	3.00	4.0

Table 3

Effects of the optimized diet on nitrogen and methane emissions at various stages of lactation, depending on milk yields in Latvia in 2019, calculated employing the NorFor Model

Indicator	Early lactation <60 DIM	Mid-lactation 60–280 DIM	Late lactation >280 DIM	Dry period
Small farms (≤10 cows) with an average yield of 6273 kg per lactation				
Crude protein, g kg ⁻¹ DM	134	120	111	110
N in excrement and urine, g d ⁻¹	233.5	213.9	193.5	164.8
Methane MJ kg ⁻¹ ECM	0.93	1.17	1.48	-
Planned yield ECM, kg d ⁻¹	23.6	19.9	15.6	-
Milk yield per kg of dry matter, kg kg ⁻¹ DM	1.45	1.20	0.88	-
Medium farms (11–300 cows) with an average yield of 6843 kg per lactation				
Crude protein, g kg ⁻¹ DM	152	149	112	120
N in excrement and urine, g d ⁻¹	286.4	304.9	177.9	170.5
Methane MJ kg ⁻¹ ECM	0.90	1.13	1.30	-
Planned yield ECM, kg d ⁻¹	25.6	22.2	16.5	-
Milk yield per kg of dry matter, kg kg ⁻¹ DM	1.52	1.24	0.99	-
Large farms (≥301 cows) with an average yield of 10132 kg per lactation				
Crude protein, g kg ⁻¹ DM	163	140	115	117
N in excrement and urine, g d ⁻¹	417.1	346.2	230.1	144.5
Methane MJ kg ⁻¹ ECM	0.81	0.96	1.09	-
Planned yield ECM, kg d ⁻¹	37.4	33.2	25.7	-
Milk yield per kg of dry matter, kg kg ⁻¹ DM	1.64	1.42	1.14	-

more feed, yet the feed stays in the rumen for a shorter time and is also exposed to rumen microorganisms for a shorter time, which significantly affects the decomposition (digestion) of feed in the cow's body. Due to the limited dry matter absorption capacity of dairy cows, it is important that high-yielding cows are fed high-quality fodder and concentrates. The main sources of nutritional energy for the maintenance of the cow's body and the production of milk are sugars and starch (Fuentes-Pila *et al.*, 2003; Guyer & Owen, 2014).

It is recommended to reduce the CP content in the dry matter of the cow diet to 15–16% for higher productivity cows (> 30 kg of milk per day) during early lactation, to 14–15% for lower productivity cows (< 30 kg of milk per day) during early lactation, while the CP content in the dry matter of the cow diet during mid- and late lactation should not exceed 12–14% (Bittman *et al.*, 2014). In practice, the level of CP in livestock diets is often higher than actually needed, as livestock diet specialists include 5–15% more CP in the livestock diets than necessary. J.E. Nocek and J.B. Russell (1988) have pointed out that microbes can be starved for nitrogen when rumen available protein is

low (< 30%). If the protein available in the rumen is more than 60%, there are high nitrogen losses even if there is a large amount of available carbohydrates. By decreasing availability of CP content in the diet to 14% milk secretion increases, but no response at a 16% CP content in the diet. The previous research studies have found that in Latvia, dairy cows on intensive farms are provided with, on average, up to 30.0 kg of feed dry matter per day, which tends to decrease during lactation. On such farms, the amounts of dry matter and CP fed per cow per day is 28.8 kg and 4.63 kg, respectively, during early lactation and 22.8 kg and 2.56 kg during late lactation. During early lactation, high-yielding cows face a nutrient deficiency of 5%, yet near late lactation and during the dry period, a slightly higher nutrient intake is provided to enable the cows to regain lost body reserves and prepare for the next lactation (Degola *et al.*, 2016).

By employing the NorFor Model, the research designed dairy cow diets, depending on milk yield, and adjusted the diets to different stage of lactation, which allowed concluding that at a 15–16% CP content in the cow diet during early lactation, the amount of N in excrement and urine was 90–180 g

d⁻¹ larger and the amount of methane was 0.08–0.69 MJ kg⁻¹ ECM smaller for high-yielding cows than for lower productivity cows. During mid-lactation, reducing the CP content in the diet by an average of 10 g kg⁻¹ DM at a milk yield above 10 000 kg per year, the trend is similar (Table 3).

Reducing the CP content per kg of feed dry matter by a further 20–30 g during late lactation reduces N emissions from excrement and urine regardless of milk yield. During the dry period, N emissions are even lower at a 11–12% CP content in the diet. The amount of methane per kg of ECM during late lactation increases, which could be explained both by a decrease in milk yield and the proportion of easily digestible nutrients – concentrates – in the diet. On intensive dairy farms in Latvia, fodder includes grasses, incl. papilionaceous grasses, and maize silage, with concentrates and other additives being added to meet the energy and mineral requirements of the cows. On medium dairy farms, the main cow feed is pasture grass during summer, and grass silage and hay during winter. Therefore, N and methane emissions vary from farm to farm. Farmers' choice to feed their cows self-produced feed is crucial in assessing the efficiency and environmental impacts of milk production.

The findings of the present research are also confirmed by the findings made by other scientists concluding that feeding livestock an amount of CP that ensures metabolism optimizes the synthesis of microbial proteins, maximally converts the nitrogen available in the diet into milk and reduces N emissions from livestock urine (Bittman *et al.*, 2014). The diet models designed reveal that it is possible to group and feed livestock according to their needs and farming conditions, and this is one of the main prerequisites for reducing N emissions. The NorFor Model allows the optimization of diets by including concentrates, roughage and other feedstuffs that increase the efficiency and profitability of the diets, thereby improving livestock welfare and reducing environmental impacts. A typical dairy cow diet containing grass silage as the main feed can lead to N and energy imbalances as well as low N use efficiency. A computer application NorFor makes it possible to control GHG emissions on the farm, especially methane, yet the methane represents only approximately half of the total GHG emissions from milk production. However, feed production, i.e. the cultivation of fodder crops in the field and feed imported into the farm contribute to a large proportion of emissions (Nordic Feed Evaluation System, 2020). The interaction between livestock management, feed production and fertilizer management, as well as the various associated emissions, are difficult to quantify, as well as to quantify the overall climate impact of

the activities. Research studies have found that N emissions are also reduced by smaller feed particle sizes, which contribute to the digestion of grain starch in the rumen. By feeding a balanced amount of digestible and indigestible protein and sugars to high-yielding dairy cows, the intake of N by the cows could be reduced to approximately 600–650 g per day (Ipharraguerre & Clark, 2005). A cow diet should be designed to facilitate fermentation in the lower intestinal tract without interfering with rumen fermentation. This could be stimulated by fibres that are able to ferment but are not affected by the rumen microflora (Van Vuuren *et al.*, 1993). Since acid-producing bacteria are concentrated in the lower intestinal tract, the risk of higher methane emissions is low (Bittman *et al.*, 2014).

By optimizing the CP content in the cow diet, it is possible to achieve an adequate milk yield during the entire lactation, producing 1.2–1.6 kg of milk per 1 kg of feed dry matter (Table 3), thereby contributing to both emission reduction and economic efficiency.

Potential for ammonia and GHG emission reduction

By optimizing the content of CP, sugar and non-starch polysaccharides (cellulose, hemicellulose) in the diet for dairy cows, the main benefit would be a smaller amount of nitrogen excreted, which would subsequently lead to lower emissions from manure. Considering the data used for 2018 emission calculation from the current 2020 ammonia emission inventory and achieving a 1% reduction in the CP content of the diet, the amount of nitrogen excreted by dairy cows could be adjusted to 104.4 kg from 115 kg per year. The projection is based on the diets designed within the project for small, medium and large dairy farms included in the ADC database at the milk yields of 6273, 6843 and 10132 kg, respectively, per lactation. However, projections of agricultural activity show a significant increase in the average milk yield from 6500 kg in 2020 to 8000 kg in 2030 and 11000 kg by 2050, which might indicate an increase in the number of livestock farmed by large farms that have set a higher CP content in cow diets. In this situation, the CP content cannot be changed to be incorporated in the National Inventory Report, and the emission reduction cannot be achieved based on this parameter.

Conclusions

Farmers in Latvia need to make increasing efforts to meet ammonia emission reduction targets. Improvements in diets for dairy cows can make a significant contribution to reducing emissions. The livestock diets designed based on scientific recommendations ensure optimal livestock nutrition and milk yields aligned with cow productivity and reduce ammonia emissions without making additional investments. The total reduction of ammonia emissions

in Latvia was calculated based on a projection of a decrease of 0.1 heifer per dairy cow. According to a long-term projection, ammonia emissions could be reduced by 0.051 kt by decreasing the number of new heifers by 12.54 thou. at the planned increase in the lifespan of dairy cows by 2030. Due to a lack of reliable and complete information on diets for dairy cows, it is not possible to determine the exact potential for ammonia and GHG emission reduction. The emissions could also be reduced by intensifying milk production as projected for agriculture. Expert assessments indicate that the diets currently fed to livestock on farms often do not meet the nutritional requirements, causing a number of problems related to agricultural production and the environment; therefore,

the focus on improving diets for dairy cows is critical to the development of the sector. Knowledge transfer, in which agricultural consultants are a key element, is also an important factor in the implementation of this measure.

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POST FIRE GROUND VEGETATION DEVELOPMENT OVER 25 YEARS

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Abstract

Fire has been a part of natural disturbance regime in boreal and to some extent also hemiboreal forests, affecting soil and light conditions, seedbanks, trees and ground vegetation. The most significant factors affecting occurrence, severity and size of forest fires are anthropogenic, weather and the environment, all of which are changing due to human-caused climate change. This paper discusses medium term (25 years) vegetation development in five different biotopes after fire disturbance. Sample plots were established in Slitere Reserve (now National park) in north-western Latvia on areas affected by large fire in 1992. Data were collected in 1993, 2002 and 2017. The aim of the study was to characterize the regeneration and succession of ground vegetation after the fire.

In 1993, species such as bog-rosemary (*Andromeda polifolia*), heather (*Calluna vulgaris*) and cloudberry (*Rubus chamaemorus*) were observed in the ground vegetation a year after the fire. In 2002 liverworts appeared, indicating that the bog has acquired more stable and wetter conditions, but in 2017, liverwort mosses were no longer present and the percentage cover of *Rubus chamaemorus* decreased significantly and *Calluna vulgaris*, *sphagnum sp.*, and *Betula pendula* were present in large quantities in the bog. Comparing these studied years, it can be concluded that all these years the biotopes and species have continuously developed and are regenerating.

Key words: fire disturbance, long-term recovery, vegetation regeneration, hemiboreal forests.

Introduction

Fires is a part of natural disturbances in hemiboreal forests and has profound influence on vegetation succession and biodiversity (Granström, 2001; Jõgiste *et al.*, 2017). Most of the fires had been human-induced; however, meteorological conditions play an important role both in initial stages of forest fire occurrence as well as potential of its spread and severity (Donis *et al.*, 2017; Kitenberga *et al.*, 2018). Bogs are an important part of the forest ecosystem, as moist wetland habitats, bog burns less often than forests, and the few fires that do occur are usually limited to the margins (Sillasoo *et al.*, 2011). The development of vegetation after a fire mainly depends on two factors: fire severity, and the structure of vegetation before the fire (Sillasoo *et al.*, 2011). Frequency of fires has increased as a result of global warming (Flannigan *et al.*, 2006). Habitat recover after fire disturbance differs from that of any other severe disturbance (Wang & Kembal, 2005) due to influence to recovery of trees as defining element of forest ecosystem (Mara Kitenberga *et al.*, 2020), as well as effect on organic matter and thus disruption of nutrient supply differing from any other severe human-induced or natural disturbance (Čakšs *et al.*, 2018; Jansons *et al.*, 2016; Samariks *et al.*, 2020, 2021). The development of burned biotope depends on how quickly the fire is extinguished and what is done with the stand after the fire, for example, whether salvage logging is carried out or left for natural regeneration (Kārklīņa *et al.*, 2020).

Climate changes significantly affect not only the increment of trees (Augustaitis *et al.*, 2015; Jansons *et al.*, 2015) or damages directly (Zeltiņš *et al.*, 2018;

Zeltiņš *et al.*, 2016) or indirectly (Arhipova *et al.*, 2015; Burneviča *et al.*, 2016), but also abiotic damages, like occurrence of forest fires (Drobyshev *et al.*, 2021). The fire significantly affects the dynamics of forest development by changing soil properties, limiting fire-sensitive species and promoting the spread of pyrophilic species (Bond *et al.*, 2005; Certini, 2005). An intensive fire could impact the future regeneration of the understory structure. However, contrary to other disturbances, fire is a disturbance whose strength and nature can influence the composition of the concrete forest stand, such as the composition of vegetation and the density of undergrowth trees (Bond *et al.*, 2005). For example, in a habitat where dominant species are heather and juniper, the fire will spread much faster and more widely throughout the area (Mallik & Gimingham, 1984). Forest fires typically divide into three groups based on their intensity and severity: 1. Ground fire – fire spreads in peat or humus layer, often without visible flames above ground level; 2. Surface fire – fire spreads in litter and undergrowth vegetation; 3. Crown fire – fire spreads from tree crown to crown, which is high-intensity stand-replacing fires (Roga, 1979).

Also, the speed and direction of vegetation succession are determined by soil factors and tree crown openness after fire and management (salvage logging) (Nilsson & Wardle, 2005), and are linked to post –disturbance stand characteristics (Bādērs *et al.*, 2021). Light conditions are changing during the forest succession; more diverse vegetation may develop in the burned area, and more shade-intolerant tree species may also enter (Hart & Chen, 2017). Also, fire

disturbances can change the pattern of competition between stand and ground vegetation, resulting in changes in vegetation structure (Angelstam & Kuuluvainen, 2004). Most of post-fire studies have focused on tree recovery (Angelstam & Kuuluvainen, 2004), but studies about vegetation development after fire data were collected shortly after a fire (Marozas *et al.*, 2007; Schimmel & Granstrom, 1996), especially researches about different biotopes like bogs are lacking. Several studies indicate that after fire at the beginning of the stand succession when topsoil is revealed, rapidly developing heather, which is a well-adapted species in such condition and can form a monodominant cover in a stand (M.-C. Nilsson *et al.*, 1996; Parro *et al.*, 2009; Reich *et al.*, 2001). Shrub layer starts to recover and stabilize within 5-15 years after burning, but the complete structure of the forest stand re-establishes 120–140 years after the fire (Gorshkov & Bakkal, 1996), even so much more rapid recovery can be expected and is observed after natural disturbances (Baders *et al.*, 2017). It is crucial to understand the development of understory vegetation growth after the fire. The bog has reached the recovery level of the ecosystem, ruderal and pioneer species have disappeared (Pakalne, 1998). Furthermore, any information that provides an accurate insight into this recovery is relevant. Therefore, any information about the forest stand development after the fire disturbance in a long-term period is essential (Kitenberga, 2019), where in our case, there are different bog habitats where forest areas are also included.

The aim of the study was to characterize the regeneration and succession of ground vegetation after the fire, based on the species composition of the ground vegetation. We hypothesized that: 1) 25 years after the fire, the vegetation has changed compared to the vegetation data in previous years 2) over time, pioneer species have disappeared, and the characteristic species are dominating, indicating a complete recovery of the studied site.

Materials and Methods

In the summer of 1992, a forest fire broke out in Slitere Reserve's territory, where 3200 ha of forests and bog were burned. To find out the condition of plant communities and the course of regeneration, the study already started one month after the fire and continued until 2002 (I. Rēriha). According to Latvian State Forest data, vegetation data were collected in five forest quarters (70; 85; 91; 110; 127) which best describe the whole bog area and include the most characteristic biotopes. In 1992, permanent plots were created to return every year and find each sample plot and count the vegetation.

The placement points of the permanent sampling plots were selected at random principle, where

40 points selected and marked in the three forest quarters, 60 points in the quarter of 70, and 20 points in 91 quarter. At each selected point, 50 x 50 cm sample plots which were oriented diagonally (each plot corner oriented to the north, south, east and west) were created. Sampling plots were located in the following habitats: 1) high bog (PU) – bog with mosses and few pines up to 1.5 m high; 2) old dunes *kangars* (K), – a dry habitat which is similar to dry pine forests; 3) old flat dunes *lēzens kangars* (LK) – where the absolute height does not exceed 0.5 m; 4) marsh (ZP); 5) bog (PA) – high bog with pines up to 2 m high; *niedrājs* (N) – wet peat biotope.

According to the same method as in previous years, the latest vegetation data was collected in 2017 (Latvian State Forest Research Institute "Silava"). As it was not possible to identify all the plots from previous years, the statistical analyses included only data from those identified plots (in total 640 plots were identified). To see the differences and tendencies of vegetation development, the data of 1993, 2002 and 2017 were used in the analyses (in total 372 sampling plots). All analyses performed in the statistical program R 4.1.0 (R Core Team, 2020), using packages "vegan", "readxl", "tidyverse", "ggrepel". The ground cover vegetation communities were assessed by the Detrended Correspondence Analysis (DCA), a multivariate orthogonal ordination method. The analysis of similarities (ANOSIM), a non-parametric ANOVA-like test based on the ranked dissimilarity matrix (Clarke 1993), was used to compare species composition between the years.

Results and Discussion

The statistical comparison of the ground cover vegetation between the selected years (1993, 2002 and 2017) showed significant (p -value < 0.001) differences amongst all years. This shows that the vegetation has changed over the last 25 years and the current vegetation in the last year of the survey is different. But in Figure 1 of the ordination, it can be seen that the growing conditions in biotopes in 2002 and 2017 were different compared with 1993, where the grouping of species is more pronounced. The first two DCA ordination axes were significant (p -values < 0.01) and showed that the vegetation and growth conditions of the analysed biotopes have changed over the years (Figure 1). These results indicate a continuous change in the composition of the plant species, where new species have been introduced in each period. First axis of the DCA analysis clearly presents light conditions, where it can be seen that the amount of light decreases due to the regeneration of trees such as silver birch *Betula pendula* and more mosses that can grow in shady conditions: *Plagiomnium affine*, *Climacium dendroides*, etc. The gradient captured by the second

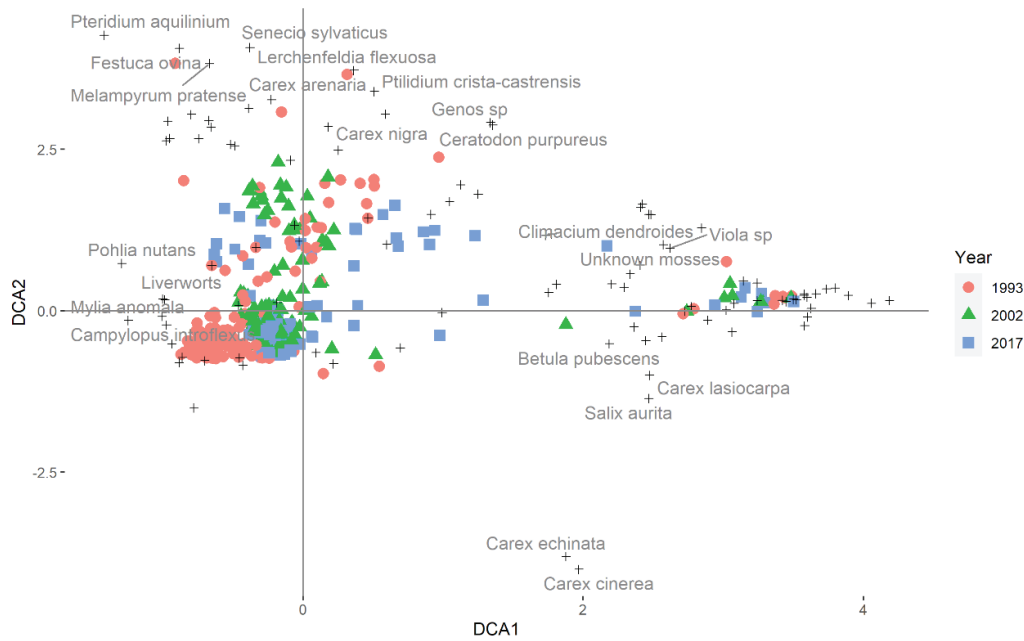


Figure 1. The detrended correspondence analysis ordination of the ground cover vegetation in all studied biotopes by years.

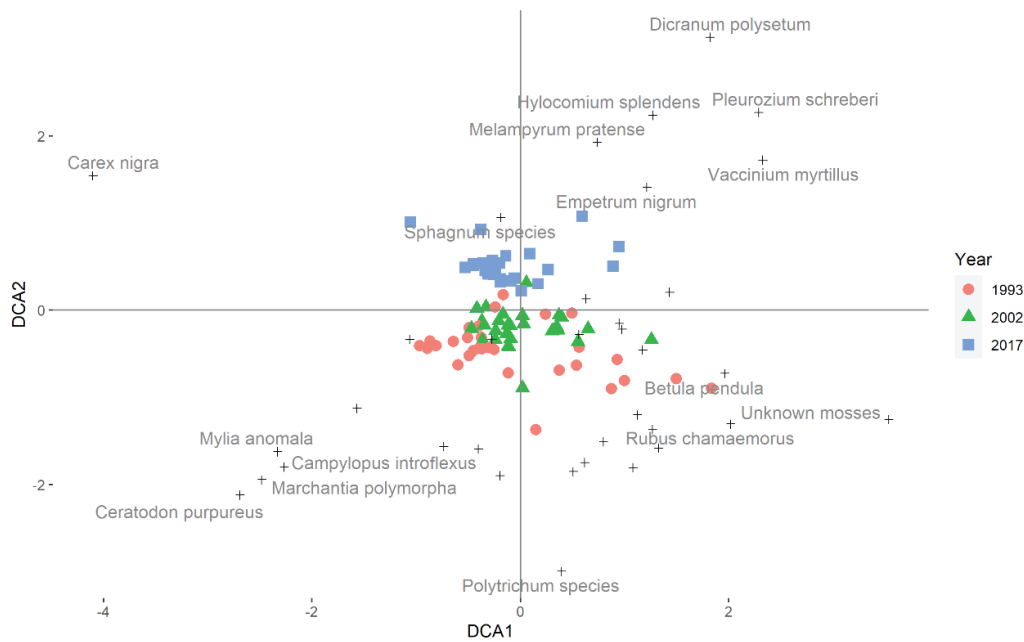


Figure 2. The detrended correspondence analysis ordination of the ground cover vegetation in the high bog biotope by years.

axis (DCA2) might be related to the moisture regime of the biotopes, as in the upper part of the axis are species which are growing in dry areas (*Cladonia species*, *Festuca ovina*, *Deschampsia flexuosa*) which indicates that by 2002 the moisture regime had increased and dry habitat species had disappeared, because, as we can see in Figure 1, these species only occurred in 1993 (Figure 1) (Frego, 1996).

Sphagnum species also showed a continuous regeneration ten years after the fire disturbance. The percentage cover of *sphagnum* moss species in the year 1993 was 4.6%, but between the year 2002 and the year 2017, sphagnum mosses have a stable percentage cover: 52% and 58%, respectively. As well as in the biotopes, where in 1993-year heather was a minimal percentage cover (~ 2%) (except for

ZP) showed high cover in 2002 (~ 40%) maintaining similar cover in 2017 as well. These results showed the contradictory result with other research about the fire disturbance, which says that five years after the fire, the biotopes, where are dry growth conditions, must change from the dominance of the heather to the dominance of cowberries (*Vaccinium vitis-idaea*) and

bilberries (*Vaccinium myrtillus*) (Parro *et al.*, 2015), which did not happen in our study, where in our dry biotopes (*kangars* and *lēzens kangars*), cowberries and bilberries almost disappeared, which is in line with the fact that the limiting factor for these shrubs is fire (Niklasson & Granström, 2000; Schimmel & Granstrom, 1996). Looking at each habitat separately

Table 1

Percentage cover of ground vegetation in the studied biotopes (K – kangars; LK – lēzens kangars; N – niedrājs; PA – bog; PU – high bog; ZP – marsh)
(Liverwort mosses were not identified by species; hence all are defined as: *liverworts*)

Biotope	K			LK			N			PA			PU			ZP		
	1993	2002	2017	1993	2002	2017	1993	2002	2017	1993	2002	2017	1993	2002	2017	1993	2002	2017
<i>Liverworts</i>		3.7			3.7						7.4			9.8				
<i>Andromeda polifolia</i>			0.1	2.2	8	1.1				2.1	10.9	0.3	5.1	12.3	0.3			
<i>Aulacomnium palustre</i>		4.3	2.2		9.9	1.5		15		0.2	12.4	1.5	1	12.1	1.3	0.25	6	
<i>Betula pendula</i>		3.7			3.7	0.25					3.75	1.6		3.8	0.8			2.4
<i>Betula pubescens</i>		1.4		1.2	4.3		1	11.2		1.5	10		0.3	5.6		3.8	7.9	
<i>Calluna vulgaris</i>	2	30.3	31.7	3.6	26	34.				3	28.5	36.4	6.3	22.1	33.3			
<i>Cladonia species</i>		22.4	10.6		13.3	3.6		3.7			5.3	2.5		5	0.1			
<i>Eriophorum vaginatum</i>		3.7	0.2	4.5	14.03	15.7	4	11.2		15.7	22.0	8.5	14.2	22.7	17			0.1
<i>Ledum palustre</i>	0.2	9.3	0.2	3.0	18.2	7.7	4.	27.5		9.4	28.7	14	6.9	18.8	7.3		3.8	
<i>Oxycoccus palustris</i>			0.1	1.3	13.7	3.4	0.5	21.2	1.5	4.4	18.6	4.2	5.3	20.9	4.4	0.2	6.3	1.8
<i>Peucedanum palustre</i>						0.75											7.5	0.4
<i>Pinus sylvestris</i>	0.5	6.2	1	0.4	6.3	3.71	0.25			0.4	5.6	1.5	0.3	3	0.6	0.2		0.2
<i>Pleurozium schreberi</i>		6	19.5		11.2	32.7					2	2		3.7	16.4		1	2.3
<i>Polytrichum juniperinum</i>	0.2	36.2	1.4	2.9	15.2	10.3	7.5	7.5	6.5	3.1	22.7	2.3	2.6	17.3	2	3.75	7.5	0.5
<i>Rubus chamaemorus</i>		0.2		13	23.3	0.62				15.3	21.5	5.6	14.0	21.7	5.1			
<i>Sphagnum species</i>		3.7		0.2	19.2	54.8	27.5	83.7	89	6.2	53.7	64.9	10.1	55.13	69.3	11.3	16.2	2.3
<i>Vaccinium myrtillus</i>	1	11.7	0.6	6.9	19.6	15.2				12.8	12.1	0.9			2.7			
<i>Vaccinium uliginosum</i>	0.2	3.7	1.2	10.8	23.0					5.2	23.3	11.2						
<i>Vaccinium vitis-idaea</i>	1.8	12	3.9	5.9	22.1	7.2				4.8	10.5	2.4	6.7	12	5.9		7.5	0.12

in the DCA analysis, it can also be seen that the composition of the species is variable, but 10 years after the fire the biotope growth conditions are more stable and are characterized by more typical species (Figure 2; as an example, a high bog is inserted), also statistical analysis showed the difference between the species in the studied years. Variability in species cover over the studied years can also be seen by visually looking at the table with biotopes and the percentage cover of the most common species (Table 1).

Conclusions

1. 25 years after the forest fire, biotopes showed continuous vegetation development throughout the research period.

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2. The vegetation percentage cover of certain species indicates that first signs of stability of ground cover is observed 10 years after the fire, which indicate the recovery after fire.
3. Fire is a significant disturbance that has a long-term effect on biotope.

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SOIL CARBON STOCK IN FERTILIZED FOREST STANDS WITH MINERAL SOILS

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Abstract

Forest mineral soil is one of the terrestrial carbon pools, and changes in forest management practices can affect the carbon stock in forest soil. The purpose of the study is to estimate temporal fertilization impact on mineral soil organic carbon stock, depending on fertilizers applied, forest stand type, different dominant tree species of the stands. Coniferous and birch forest stands with mineral soil in the central and eastern part of Latvia were selected for the experiment. The fertilizers used were wood ash and nitrogen containing mineral fertilizer. No significant differences in organic carbon stock in O horizon were detected 2–5 years after fertilization. A tendency of smaller organic carbon stock in upper mineral soil layers (0–10 cm, 10–20 cm) was found in most part of objects. Significantly smaller organic carbon stock was found in upper mineral soil layers (0–10 cm and 10–20 cm) in birch stands with wet mineral soil treated with ammonium nitrate if compared to the control plots, possibly due to a different soil moisture regime of forest stands. The positive and significant correlations between soil organic carbon and nitrogen stocks were found in most part of the objects.

Key words: wood ash, nitrogen containing mineral fertilizer, organic carbon, forest soil.

Introduction

Forests have an essential role in the global carbon cycle, and forest soil is one of the terrestrial carbon pools. Changes in carbon stock of boreal forest soils are mainly the result of global warming, deforestation and occasional periods of drought and fire. On average, circa 60% of carbon is stored in soil of boreal forests (Pan *et al.*, 2011), and mineral soil is the second important carbon pool, reaching 31% of total forest ecosystem carbon, right after the living tree biomass – 59% (Kēniņa *et al.*, 2019). Organic matter has an impact on quality and structure of soil, chemical and biological properties (Walsh & McDonnell, 2012).

Several local studies have been carried out in this field. A research in regard to the impact of surface fire on O layer in a dry Scots pine forest indicated a significant impact on reduction of a carbon stock in O layer in fire affected forest areas, while no significant changes were detected in mineral soil layers (Bārdule *et al.*, 2017). A study conducted in over-mature Norway spruce stands showed no significant differences between forest site types (Kēniņa *et al.*, 2018). Furthermore, a study in over-mature Scots pine stands showed no trends in O horizon and mineral soil carbon stock changes regarding the stand age, within the range of 163–218 years (Kēniņa *et al.*, 2019).

Forest soil fertilization can improve the growth of trees on nutrient-poor site and reduce deficiency of nutrients. Forest fertilization can be commenced during the whole rotation or 10–15 years before the regenerative felling, respectively, forest fertilization can be conducted once during the rotation period or can be repeated to ensure continuously high growth rates (Högberg *et al.*, 2006). Studies in Latvia have reported a short-term impact of forest soil fertilization

with wood ash on the growth of stand (Okmanis *et al.*, 2016; Okmanis *et al.*, 2018) while other studies reported a long-term effect of forest soil fertilization on growth of trees (Jansons *et al.*, 2016; Libiete *et al.*, 2016; Petaja *et al.*, 2018).

Long-term boreal forest fertilization experiment with repeated application of nitrogen containing fertilizer has showed a positive effect on the growth of trees and, as a result, carbon sequestration (Högberg *et al.*, 2006). It has been estimated that by forest soil fertilization in Latvia can be cumulatively reduced 635,000 CO₂ eq. in 10 years (Petaja *et al.*, 2018).

Soil quality and the content of organic matter of soil have been relevant topics of studies. The topicality of this study is based on necessity to increase CO₂ removals in forest ecosystem and considerable short- and long-term greenhouse gas (GHG) mitigation potential of forest fertilization in hemi-boreal forest stands (Federici *et al.*, 2015). The aim of the research is to evaluate temporal impact of fertilization with wood ash and ammonium nitrate on soil organic carbon stock in forests stands with mineral soils.

Materials and Methods

Study sites and treatment

In total, 49 research sites were established in the central and the eastern part of Latvia (Table 1). The dominant tree species in the study sites are Scots pine (*Pinus sylvestris* L.), Norway spruce (*Picea abies* (L.) H.Karst.) and birch (*Betula* spp.). In order to estimate the possible impact of treatment on the organic carbon (C_{ORG}) stock in forest soil, the plots were established in the forest stands with dry mineral soil, naturally wet mineral soil and drained mineral soil. The experimental sites received the following treatment: wood ash (WA), wood ash and ammonium nitrate (WA+NH₄NO₃) or

Table 1

Description of research objects and fertilization

Soil type and moisture conditions	Dominant tree species	Number of forest stands	Age of stands	Dose: t *WA or **NH ₄ NO ₃ ha ⁻¹	Fertilizer spreading	Date of treatment
wood ash treatment						
Dry mineral soil	Norway spruce	3	50-54	2; 3 t WA	mechanically	11.2014; 05.2017
Drained mineral soil	Norway spruce	3	44-53	3; 4; 6; 8 t WA	manually/ mechanically	10.2016; 12.2016; 05.2017
wood ash and ammonium nitrate treatment						
Drained mineral soil	Norway spruce	2	36-38	3 t WA + 0.44 t NH ₄ NO ₃	mechanically	02.2017; 07.2017
Drained mineral soil	Scots pine	3	51-67	3 t WA + 0.44 t NH ₄ NO ₃	mechanically	02.2017; 07.2017
Drained mineral soil	birch	2	34-37	3 t WA + 0.44 t NH ₄ NO ₃	manually/ mechanically	10.2016; 02.2017; 06.2017; 07.2017
ammonium nitrate treatment						
Dry mineral soil	Norway spruce	7	25-83	0.44 t NH ₄ NO ₃	manually/ mechanically	09.2015; 07.2017
Dry mineral soil	Scots pine	21	24-130	0.44 t NH ₄ NO ₃	manually/ mechanically	09.2015; 06.2017; 07.2017
Dry mineral soil	birch	3	44-72	0.44 t NH ₄ NO ₃	manually/ mechanically	06.2017; 07.2017
Wet mineral soil	birch	2	23-48	0.44 t NH ₄ NO ₃	manually/ mechanically	05.2017; 06.2017
Drained mineral soil	Norway spruce	2	28-37	0.44 t NH ₄ NO ₃	manually/ mechanically	09.2015; 06.2017

*wood ash; **ammonium nitrate

ammonium nitrate (NH₄NO₃). Control plots (C) were left without the treatment. Wood ash used in this study were taken from local heating- and power plants: NewFuels RSEZ, Ltd.; Latgran, Ltd.; "Graanul Invest, Ltd. and Salaspils siltums, Ltd.

Collection and analysis of soil samples

Collection of samples was conducted in 2019, namely, 2-5 years after the fertilization. Two replicates of 10 cm x 10 cm large O horizon samples were collected in each plot. Soil samples were collected at fixed depths: 0–10 cm, 10–20 cm, 20–40 cm and 40–80 cm. The samples were taken at each plot, ensuring 2 replicates per plot.

Collected O horizon samples were milled till fine powder, soil samples were manually comminuted and sieved through 2 mm sieve. Fine fraction was used for analyses assuming coarse fraction to be free of C_{ORG} and nitrogen (N). The samples were prepared according to the ISO 11464:2005. Bulk density was determined according to ISO 11272:2017. Content of total carbon (C_{TOT}) content was determined using elementary analysis according to ISO 10694:2006 and inorganic carbon (C_{CARB}) – by volumetric method

according to ISO 10693:2014. Concentration of C_{ORG} was calculated as the difference: C_{TOT} – C_{CARB}. The concentration of total nitrogen (N_{TOT}) was determined using elementary analysis according to ISO 13878:1998.

Data analysis

The C_{ORG} stock was calculated for different soil layers: 0–10 cm, 10–20 cm, 20–40 cm and 40–80 cm. In addition to these soil layers, the average C_{ORG} stock in soil from control and fertilized plots was compared in the following soil layers: 0–20 cm, 0–40 cm and 0–80 cm. The C_{ORG} stock was calculated according to the formula (1):

$$(1) CS = \frac{SBD \times H \times (100\% - P_{2mm})}{100(cm)} \times \frac{SOC}{1000}, \text{ where:}$$

- CS – content of C_{ORG} in 1 ha of the soil/O horizon (t C_{ORG} ha⁻¹);
- SOC – C_{ORG} content (g kg⁻¹);
- SBD – bulk density (kg m⁻³);
- H – thickness of a soil/O horizon layer (cm);
- P_{2mm} – volume of the fraction of > 2 mm particles in the sample (%).

Table 2

**Impact of forest soil fertilization on C_{ORG} stock ($t\ ha^{-1}$) in O horizon
(mean values \pm standard error of the mean)**

Type of fertilizer	Wood ash		Wood ash and ammonium nitrate	Ammonium nitrate		
	Dry mineral soil	Drained mineral soil	Drained mineral soil	Dry mineral soil	Wet mineral soil	Drained mineral soil
Control plots	14.0 \pm 6.5	6.4 \pm 2.4	12.9 \pm 1.6	13.3 \pm 0.9	7.8 \pm 2.3	7.2 \pm 0.9
Fertilized plots	12.5 \pm 3.0	11.2 \pm 3.0	9.9 \pm 1.3	11.6 \pm 0.7	8.8 \pm 2.3	8.2 \pm 1.3

Normal distribution was tested by Shapiro-Wilk normality test. The data ranges were not normally distributed; therefore, non-parametrical test was used. The non-parametrical Wilcoxon rank sum test with continuity correction was used to compare the C_{ORG} stock among control plots and plots, where fertilizers were applied. The Spearman's rank correlation was used to compare relationship between C_{ORG} and N_{TOT} stock of the trial objects. The strength of correlation coefficient was evaluated according to Akoglu (2018). Tests were conducted at a 95% confidence level in program R (R Core Team, 2018).

Results and Discussion

The results are summarized according to the applied fertilizer and forest stand type. Table 2 summarizes the average C_{ORG} stock in O horizon. No statistically significant differences were found between control and fertilized plots. No trends in results were found among the trials or forest stand types. No significant impact on O horizon was reported in similar study with wood ash application (Libiete *et al.*, 2016). The differences in C_{ORG} stock among the plots can be explained with the natural O horizon variability. The average C_{ORG} stock in O horizon is smaller in comparison to average values in Latvia estimated earlier – 21 $t\ ha^{-1}$ (Bārdule *et al.*, 2009) or average C_{ORG} stock in O horizon in European forests – 22.1 $t\ ha^{-1}$ (De Vos *et al.*, 2015). These differences in average C_{ORG} stock in O horizon may be explained with different site conditions of the experiments, because the organic matter content in O horizon depends on different factors, such as disturbances (Bārdule *et al.*, 2017), moisture regime of the stand (Błońska & Lasota, 2017) and the dominant tree species of the stand (Butlers & Lazdins, 2020) while the calculated C_{ORG} stock is quite similar to the mean value determined in a study carried out in local Scots pine stands with dry mineral soil – 15.2 $t\ ha^{-1}$ (Kēniņa *et al.*, 2019).

The average C_{ORG} stock in different soil layers in the research objects after the fertilization are

summarized in Table 3. Statistically significant differences ($p < 0.01$) in average C_{ORG} stock were found in upper soil layers (010 cm and 1020 cm) in forest stands with wet mineral soil. The average C_{ORG} stock in control plots in stands with wet mineral soil is 44.4 \pm 5.3 and 19.4 \pm 3.8 $t\ ha^{-1}$, and C_{ORG} stock in plots fertilized with N containing mineral fertilizer is 29.6 \pm 4.1 and 11.0 \pm 1.6 $t\ ha^{-1}$ – in 0–10 cm and 10–20 cm soil layers, respectively. The soil samples were collected in the second year after the ammonium nitrate application in these two birch stands. The soil moisture regime of these trial objects differs from other experimental sites. The average C_{ORG} stock of mineral soil determined in this study is comparatively smaller than the average value estimated in the earlier study in Latvia – 195 $t\ ha^{-1}$ (Bārdule *et al.*, 2009). But the calculated value is quite similar to results of other local studies – 88.4 $t\ ha^{-1}$ in Norway spruce stands with dry mineral soil, 88.0 $t\ ha^{-1}$ in stands with wet mineral soil (Kēniņa *et al.*, 2018) and 90.0 $t\ ha^{-1}$ in Scots pine stands with dry mineral soil (Kēniņa *et al.*, 2019). The calculated values of cumulative C_{ORG} stock in 0–80 cm soil layer varies among different plots, but the average value is close to C_{ORG} stock determined in European forests in 0–100 cm mineral soil layer – 108 $t\ ha^{-1}$ (De Vos *et al.*, 2015).

A trend of smaller C_{ORG} stock in upper soil layer (0–10 cm) of fertilized plots was detected, and to a lesser extent – in 10–20 cm soil layer. If C_{ORG} is summarized at multiple layers, on average the calculated C_{ORG} stock is smaller in fertilized plots, except for ammonium nitrate treated plots in forest stands with drained mineral soil. The difference is not statistically significant in the most cases.

The results of Spearman rank correlation between C_{ORG} and N_{TOT} in O horizon is shown in Table 4. The table summarizes only statistically significant ($p < 0.05$) results. All relationships detected are positive and ranges from moderate to very strong. The correlation found confirms that the N_{TOT} stock is higher in plots with higher content of organic matter in soil.

Table 3

Impact of forest soil fertilization on C_{ORG} stock ($t\ ha^{-1}$) in different mineral soil layers

Soil type and moisture conditions	Plot	Mean soil C_{ORG} stock in different soil layers (mean values \pm standard error of the mean), $t\ ha^{-1}$				Cumulative soil C_{ORG} stock in different soil layers, $t\ ha^{-1}$		
		0–10 cm	10–20 cm	20–40 cm	40–80 cm	0–20 cm	0–40 cm	0–80 cm
Wood ash experiment								
Dry mineral soil	¹ C	40.5 \pm 6.7	22.5 \pm 5.2	16.2 \pm 4.6	15.5 \pm 5.5	63.0	79.2	94.7
	² WA	38.4 \pm 9.2	18.1 \pm 2.7	17.5 \pm 5.4	18.2 \pm 3.3	56.5	74.0	92.2
Drained mineral soil	C	66.7 \pm 15.4	30.6 \pm 9.3	19.0 \pm 6.3	52.3 \pm 12.2	97.3	116.2	168.6
	WA	43.8 \pm 16.2	41.1 \pm 5.4	31.8 \pm 5.7	33.1 \pm 5.1	84.8	116.7	149.8
Wood ash and ammonium nitrate experiment								
Drained mineral soil	C	62.9 \pm 5.1	36.3 \pm 6.7	29.3 \pm 9.9	41.1 \pm 16.1	99.2	128.5	169.6
	WA+N	54.5 \pm 4.8	36.0 \pm 6.7	34.6 \pm 14.5	25.3 \pm 6.4	90.5	125.1	150.4
Ammonium nitrate experiment								
Dry mineral soil	C	30.7 \pm 2.3	15.7 \pm 1.3	12.1 \pm 1.0	16.8 \pm 2.3	46.4	58.5	75.3
	³ N	30.9 \pm 2.1	12.8 \pm 0.8	12.4 \pm 1.0	15.4 \pm 1.7	43.7	56.2	71.6
Wet mineral soil	C	^a 44.4 \pm 5.3	^a 19.4 \pm 3.8	7.1 \pm 2.4	12.6 \pm 3.7	63.8	71.0	83.6
	N	^a 29.6 \pm 4.1	^a 11.0 \pm 1.6	8.9 \pm 3.1	29.0 \pm 10.8	40.7	49.5	78.6
Drained mineral soil	C	63.8 \pm 9.8	32.8 \pm 2.3	14.6 \pm 4.1	15.2 \pm 3.8	96.6	111.2	126.4
	N	61.9 \pm 6.7	45.7 \pm 5.7	32.7 \pm 8.8	21.2 \pm 5.3	107.5	140.2	161.4

¹control; ²wood ash; ³ammonium nitrate; a $p < 0.05$

Table 4

Significant Spearman rank correlations (r_s , $p < 0.05$) between C_{ORG} and N_{TOT} stock in O horizons

Type of fertilizer	Wood ash		Wood ash and N fertiliz.	Ammonium nitrate		
	Dry mineral soil	Drained mineral soil	Drained mineral soil	Dry mineral soil	Wet mineral soil	Drained mineral soil
Control plots	^b 0.73	-	^a 0.89	^a 0.85	^b 0.94	^a 0.98
Fertilized plots	^b 0.76	-	^a 0.54	^a 0.58	-	^a 0.79

^a $p < 0.01$; ^b $p < 0.05$

Table 5 summarizes only statistically significant correlation between C_{ORG} and N_{TOT} stock in forest soil. The relationship between C_{ORG} and N_{TOT} is positive and is found in nearly all soil layers, plots and forest stand types. The correlation found between organic matter and N_{TOT} can be estimated as moderate or mostly – very strong.

These findings are in line with the results of demonstration project *BioSoil* (Bārdule *et al.*, 2009), where relationship between the content of C_{ORG} and N_{TOT} in forest mineral soil was detected ($R^2 = 0.82$).

Significant relationship between relative C_{ORG} and N_{TOT} stock in forest soil is shown in Table 6. In comparison to the correlation found between C_{ORG} and N_{TOT} stock (Table 5), correlation between the relative element stocks was found only in a part of stands. A larger N_{TOT} stock in mineral soil layer is related to a larger carbon stock.

Conclusions

1. No significant trends were found in average carbon stock in O horizon among experimental groups or different growth conditions.
2. In comparison to the control plots, a smaller C_{ORG} stock in 0–10 cm mineral soil layer was detected in the most of the fertilized plots. A statistically significant difference between control and fertilized plots was found in upper soil layers (0–10 cm and 10–20 cm) of birch stands with wet mineral soil, indicating a possible impact of ammonium nitrate on mineralization of organic matter. However, the differences may be explained also with different moisture regime and initial C_{ORG} stock in these experimental sites.
3. There is no significant difference between soil C_{ORG} stock in control plots and plots fertilized with wood ash and nitrogen. Similarly, no significant

Table 5

Significant Spearman rank correlations (r_s , $p < 0.05$) between C_{ORG} and N_{TOT} stock in mineral soil layers

Soil type and moisture conditions	Plot	0–10 cm	10–20 cm	20–40 cm	40–80 cm	0–20 cm	0–40 cm	0–80 cm
Wood ash experiment								
Dry mineral soil	¹ C	^a 0.89	^a 0.92	^a 0.87	^b 0.69	^a 0.95	^a 0.94	^a 0.87
	² WA	^a 0.91	^a 0.95	^a 0.79	-	^a 0.96	^a 0.92	^a 0.85
Drained mineral soil	C	^b 0.94	^b 0.89	^b 0.89	-	^a 0.94	^a 0.93	^a 0.90
	WA	^a 0.92	^a 0.87	^a 0.82	^a 0.67	^a 0.92	^a 0.92	^a 0.86
Wood ash and ammonium nitrate experiment								
Drained mineral soil	C	^a 0.74	^a 0.92	^a 0.83	^a 0.86	^a 0.87	^a 0.91	^a 0.90
	WA+ ³ NH ₄ NO ₃	^a 0.71	^a 0.92	^a 0.83	^a 0.80	^a 0.87	^a 0.91	^a 0.91
Ammonium nitrate experiment								
Dry mineral soil	C	^a 0.96	^a 0.93	^a 0.74	^a 0.56	^a 0.96	^a 0.87	^a 0.71
	NH ₄ NO ₃	^a 0.94	^a 0.92	^a 0.81	^a 0.70	^a 0.95	^a 0.88	^a 0.75
Wet mineral soil	C	^b 0.68	^a 0.99	^a 0.73	^b 0.66	^a 0.90	^a 0.95	^a 0.91
	NH ₄ NO ₃	^a 0.76	^a 0.79	^b 0.72	^a 0.74	^a 0.89	^a 0.85	^a 0.81
Drained mineral soil	C	^a 0.89	^a 0.95	^a 0.91	^a 0.75	^a 0.93	^a 0.97	^a 0.96
	NH ₄ NO ₃	^a 0.94	^a 0.97	^a 0.94	^a 0.83	^a 0.97	^a 0.98	^a 0.97

¹control; ²wood ash; ³ammonium nitrate; a $p < 0.01$; b $p < 0.05$

Table 6

Significant Spearman rank correlations (r_s , $p < 0.05$) between relative organic carbon and nitrogen stock (in comparison to the control plots, %) in mineral soil layers

Soil type and moisture conditions	0–10 cm	10–20 cm	20–40 cm	40–80 cm	0–20 cm	0–40 cm	0–80 cm
Wood ash experiment							
Dry mineral soil	-	-	-	-	-	^b 0.94	^a 0.95
Drained mineral soil	-	-	-	-	^b 0.94	^a 0.86	^b 0.61
Wood ash and ammonium nitrate experiment							
Drained mineral soil	-	-	-	^b 0.89	^a 0.85	^a 0.83	^a 0.84
Ammonium nitrate experiment							
Dry mineral soil	^a 0.92	^a 0.86	^a 0.53	^a 0.53	^a 0.90	^a 0.78	^a 0.72
Wet mineral soil	-	-	-	-	-	-	^a 0.88

^a $p < 0.01$; ^b $p < 0.05$

4. On average, forest fertilization with wood ash and/or ammonium nitrate does not have a significant impact on C_{ORG} stock in mineral soil 2–5 years after the fertilization.
5. A relationship between C_{ORG} and N_{TOT} stock in mineral soil was found practically in all plots – both control and fertilized, and in most of the plots – a relationship between the stock in O horizon.

6. The study has to be continued because 2–5 years period is too short to acquire the impact of fertilization on soil C_{ORG} stock.

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SHORT-TERM EFFECTS OF FERTILIZATION ON PHOTOSYNTHETIC ACTIVITY IN A DECIDUOUS TREE PLANTATION

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Abstract

Fertilization is a method to enhance tree growth and timber production. Ammonium nitrate and wood ash are commonly used fertilizers, which can be applied at the same time to increase levels of both nitrogen and other macro- and micronutrients. We studied how ammonium nitrate and wood ash fertilization affects photosynthetic activity and transpiration at leaf level in a deciduous tree plantation in former agricultural land with mineral soil, located in the central part of Latvia (Keipene parish). Additionally, we performed foliar and soil nutrient analyses. Our results support the notion that nitrogen fertilization may not result in increased photosynthetic activity. It is possible that the photosynthetic activity has increased at canopy scale along with increasing leaf area, not at leaf scale. Wood ash addition seems to have resulted in higher photosynthetic activity for hybrid alder, although it could not be explained with phosphorus availability. Although closely related to photosynthesis, in most cases transpiration was not positively affected by fertilization. Environmental factors, such as humidity, temperature and wind speed may have a greater effect on this process.

Key words: wood ash, ammonium nitrate, photosynthetic activity, transpiration, foliar nutrient levels, plantation forestry.

Introduction

Fertilization is a silvicultural practice, applied to enhance tree growth and thus to increase timber production. In forests on mineral soils, nitrogen (N) containing fertilizers are usually applied, whereas in peatland forests phosphorus (P) and potassium (K) fertilizers are mostly used (Saarsalmi & Mälkönen, 2001). In forests on mineral soils the normally applied N dose with fertilizers is 150 kg ha⁻¹ and the following growth response is 20–25 m³ ha⁻¹ (Pukkala, 2017). The effect is the most intense in the first five years; however, it may last about 12 years (Saarsalmi & Mälkönen, 2001). Ash is a by-product of biomass burning. It contains major bioavailable nutrients required for optimal tree growth: potassium (K), phosphorus (P), calcium (Ca), magnesium (Mg), and several trace elements; however, it does not contain nitrogen. Wood ash can also be used as liming material due to its high content of calcium oxide and hydroxide (Karlton *et al.*, 2008). The recommended dose of P for peatland forests is 40–50 kg ha⁻¹, and that for K is 40–80 kg ha⁻¹, which correspond to a wood ash dose of 2000–5000 kg d.w. (Sikström, Almqvist, & Jansson, 2010). In Finland, wood ash has been extensively applied to conifer stands in drained peatland forests since 1935. In Sweden, wood ash is produced on a large scale as well and applied to acidified forest soils in the southern part of the country (Lundström *et al.*, 2003). There have been studies of the impact of forest fertilization on tree growth in Latvia as well. Wood ash and potassium sulphate application significantly improved tree growth in Norway spruce stands on both drained mineral and peat soil. The effect increased continually in the following 4 years (Okmanis *et al.*, 2016). The effect of wood ash has also been evaluated for Scots

pine and Norway spruce seedlings. Ash application (5 to 10 t ha⁻¹) to restoration site on drained fertile peat soil one year before planting the seedlings resulted in an improved tree height and diameter growth. The effect was long-term and lasted 10 years after the seedlings had been planted (Jansone *et al.*, 2020).

The worldwide plantation area is still expanding and most of them are fertilized at some stage of development. In addition to increased wood biomass, another benefit of fertilizer application is a shortened rotation period (Smethurst, 2010). Silver birch is the most frequently planted tree species in Latvia, followed by Norway spruce and black alder. In an experimental Norway spruce plantation in Kalsnava, Latvia, fertilization with ammonium nitrate (NH₄NO₃), superphosphate and potassium nitrate with doses 56 kg ha⁻¹ of N, 24 kg ha⁻¹ of P and 44 kg ha⁻¹ of K, respectively, significantly increased the dimensions of trees (ca. 17% increase of stemwood volume, 7% – of diameter and 3% – of height) in long-term (Jansons *et al.*, 2016).

Photosynthesis can be defined as the process by which plants use sunlight to synthesize organic compounds from carbon dioxide and water. Transpiration is a process coupled with photosynthesis, and it is the discharge of water vapour through stomata (Tuzet, 2011). The two main functions of transpiration are reducing the temperature of the plant and providing the flow of water and nutrients to leaves. Photosynthetic response of plants to elevated concentrations of nutrients is complex and depend on many environmental and physiological factors. Studies show that tree canopy-scale photosynthesis increases either along with increasing needle N contents or additional leaf area, or both of these factors

(Evans, 1989). In an N-deficient environment, the use of organic C compounds for N assimilation and growth is restricted and less carbohydrate is exported from plant leaves (Paul & Driscoll, 1997).

The effect of N addition on photosynthesis at leaf- and canopy-scale depends on the balance between tree photosynthetic capacity and leaf area. Several studies suggest that high foliar N concentrations could lead to unbalanced nutrient availabilities. Phosphorus may play an important role in restricting leaf-scale photosynthetic capacity (Bauer *et al.*, 2004; Ellsworth *et al.*, 2015; Niinemets *et al.*, 2001; Walker *et al.*, 2014). Increased nitrogen availability and foliar concentrations do not always indicate increased photosynthetic activity. Under certain conditions nitrogen is increasingly allocated to non-photosynthetic compounds, e.g., free amino acids (Näsholm & Ericsson, 1990; Näsholm, 1994). The amino acid arginine is excessively found in needles of conifers growing in N-rich environment (Bauer *et al.*, 2004; Nordin, Uggla, & Näsholm, 2001). Arginine synthesis is often enhanced by low availability of P and several other macro- and micronutrients and could be a possible general response to environmental stress (Näsholm & Ericsson, 1990). However, most of these studies focused on the fertilization effects on conifers and needle chemistry.

Variations in photosynthetic activity have been reported as determinants of plant productivity.

Studying this parameter can provide useful information on the growth potential of certain tree species and certain genotypes (Kundu *et al.*, 1998; Orlović *et al.*, 2014). The aim of the study was to investigate how forest fertilization influences leaf-level photosynthetic activity, transpiration and foliar nutrient levels in a deciduous tree plantation.

Materials and Methods

Study site – the Keipene plantation – is located in the central part of Latvia, Ogre municipality, Keipene parish (56°55'59.3"N 25°08'15.4"E). Tree seedlings were planted in 2012 and 2013 on former agricultural land with mineral soil. In 2016, prior to fertilization, soil and leaf/needle analyses were carried out and phosphorous deficiency was diagnosed. Fertilizers were spread manually in 2017. In total, 16 parcels were fertilized with 0.44 t ha⁻¹ ammonium nitrate and in parcels, where decreased tree growth was observed, wood ash was added (3 t ha⁻¹). Wood ash was obtained from SIA Graanul Pellets pellet factory. The element concentration of wood ash was 9.6 g kg⁻¹ P, 25.96 g kg⁻¹ K., 153.32 g kg⁻¹ Ca and 11.58 g kg⁻¹ Mg. The following tree species were included in the study: silver birch (*Betula pendula* Roth.), common alder (*Alnus glutinosa* (L.) Gaertn.), wild cherry (*Cerasus avium* (L.), Moench syn. *Prunus avium* L.) and also an aspen hybrid and an alder hybrid.

Table 1

Fertilizer use per plot and characteristics of fast-growing tree plantation in Keipene

No. of plot	Tree species	Fertilized area, ha	Ammonium nitrate, kg	Wood ash, kg
18	Black alder	0.12	53	-
20	Silver birch	0.12	53	-
19b	Hybrid alder	0.06	26	180 (1.73 kg P, 4.67 kg K, 27.60 kg Ca, 2.10 kg Mg)
6b	Hybrid aspen	0.09	40	-
7	Silver birch	0.18	79	-
22	Black alder	0.12	53	-
8a	Wild cherry	0.09	40	270 (2.59 kg P, 7 kg K, 41.40 kg Ca, 3.13 kg Mg)
8b	Hybrid aspen	0.09	40	-
24	Black alder	0.14	62	-
25	Silver birch	0.14	62	-
26a	Black alder	0.08	35	-
26b	Hybrid alder	0.04	18	-
27c	Silver birch	0.08	35	-
27b	Black alder	0.08	35	-
67	Hybrid aspen	0.12	53	-
57	Silver birch	0.12	53	-
57	Silver birch	0.12	53	-

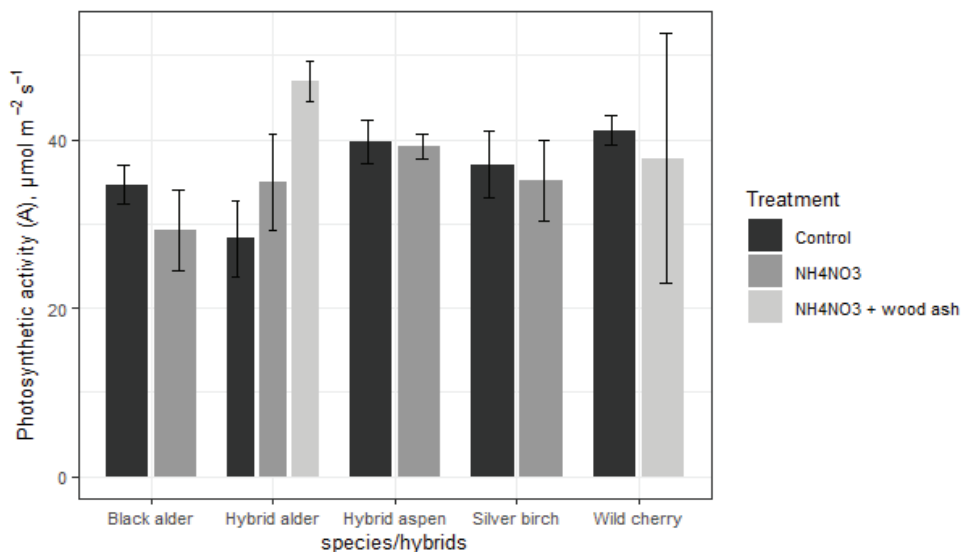


Figure 1. Photosynthetic activity (A) of fast-growing deciduous tree species and hybrids at different fertilization regimens (mean values ± SEM).

Photosynthetic activity (A) and transpiration (E) were measured with LCI Compact Portable Photosynthesis System, using the chamber for broadleaves. The photosynthetically active light intensity of leaf area (Q_{leaf}) was set to $1500 \mu\text{mol m}^{-2} \text{s}^{-1}$. Measurements were carried out for 3 trees in each parcel. The samples of leaves (3 of each tree) were collected from the upper parts of tree canopies after taking measurements of photosynthetic activity. Soil samples were collected prior to foliar measurements in 2019, from depths of 0–10 cm, 10–20 cm, 20–40 cm and 40–80 cm.

The collected leaves were dried at $70 \text{ }^{\circ}\text{C}$ and milled. Leaves were not washed prior to preparation. Soil samples were air-dried, homogenized and sieved (2 mm pore size), according to the ISO 11465:1993. To measure macronutrient levels $-N$ (g kg^{-1}), Ca (g kg^{-1}), Mg (g kg^{-1}), K (g kg^{-1}) and P (g kg^{-1}), both soil and leaf samples were microwave-digested (Mars 6 iWave. CEM), using 65% HNO_3 . Leaf extracts were analyzed with Inductively coupled plasma - optical emission spectrometer (ICP-OES, iCAP 7200 Duo Thermo Fisher Scientific) and soil extracts – with Flame Atomic Absorption Spectroscopy (FAAS, AAnalyst 200. Perkin Elmer).

Data were processed and analyzed with Microsoft Excel and Rstudio. We performed Student's T-test and Wilcoxon rank sum test with continuity correction (the test was chosen, depending on normality of data distribution) to estimate differences between the control and treatment plots at species level. Spearman rank correlation analysis was performed for foliar and soil nutrient concentrations. Statistical analyses were conducted, using software RStudio, at a 95% confidence level.

Results and Discussion

In the control plots, where hybrid alder was planted, the average value of photosynthetic activity (A) was $28.3 \pm 4.5 \mu\text{mol m}^{-2} \text{s}^{-1}$, whereas in parcel, where ammonium nitrate was spread, the value was $34.9 \pm 5.7 \mu\text{mol m}^{-2} \text{s}^{-1}$, and in parcel, where wood ash was applied additionally to ammonium nitrate, the average value was $46.9 \pm 2.4 \mu\text{mol m}^{-2} \text{s}^{-1}$. The average values of photosynthetic activity for silver birch and hybrid aspen in both control and parcels treated with NH_4NO_3 did not differ significantly. For silver birch the average values were $37.1 \pm 3.9 \mu\text{mol m}^{-2} \text{s}^{-1}$ and $35.2 \pm 4.8 \mu\text{mol m}^{-2} \text{s}^{-1}$ in control and treatment parcels, accordingly, and for aspen hybrids the values were $39.8 \pm 2.5 \mu\text{mol m}^{-2} \text{s}^{-1}$ and $39.2 \pm 1.5 \mu\text{mol m}^{-2} \text{s}^{-1}$. For black alder and wild cherry higher photosynthetic activity was recorded in control plots ($34.7 \pm 2.3 \mu\text{mol m}^{-2} \text{s}^{-1}$ un $29.3 \pm 4.8 \mu\text{mol m}^{-2} \text{s}^{-1}$ for black alder, $41.1 \pm 1.7 \mu\text{mol m}^{-2} \text{s}^{-1}$ and $37.8 \pm 14.8 \mu\text{mol m}^{-2} \text{s}^{-1}$ for wild cherry, respectively). Statistically significant increase in photosynthetic activity was found only in case of alder hybrid, when wood ash was applied along with ammonium nitrate ($p = 0.0228$, Student's T-test). It is known that for silver birch the maximum photosynthetic efficiency at full sunlight is about 10 – 50% (Perala & Alm, 1990). The comparison of the mean values of A and the calculated standard error of the mean (SEM) are shown in Figure 1.

Silver birch is able to compensate the damage of leaves and defoliation by increasing photosynthetic activity. This means that even less optimal growing conditions would not affect photosynthesis and could explain the insignificant differences between control and N treatment plots. (OECD, 2006).

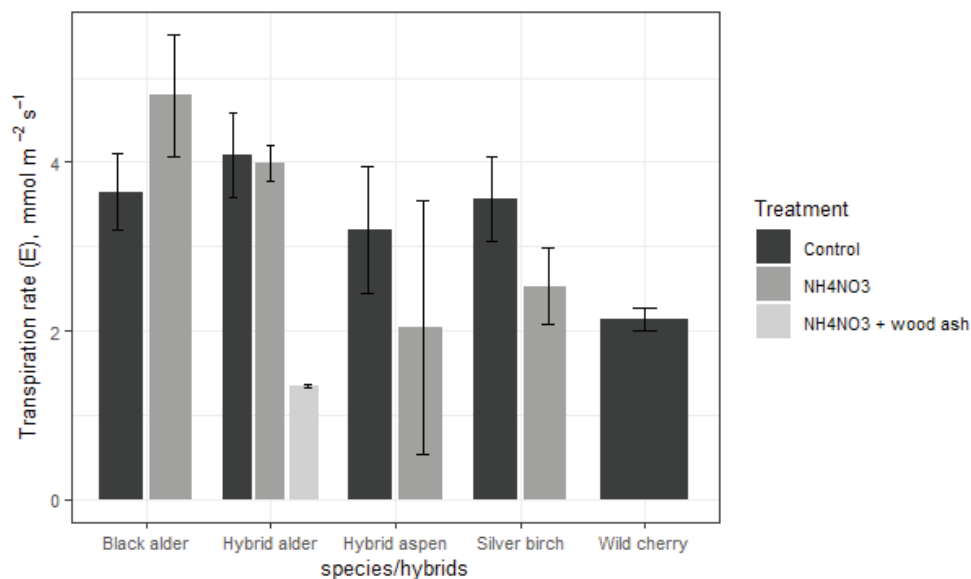


Figure 2. Transpiration (E) of fast-growing deciduous tree species and hybrids at different fertilization regimens (mean values ± SEM).

Hybrid alder shows higher photosynthetic rate in the N treatment plots, compared with black alder. The rate is even higher, when wood ash is applied. Previous studies show that hybrids express higher photosynthetic rates, which is interpreted as being a result of a heterosis effect, resulting from an enhanced expression of genes coding for CO₂ fixation-related proteins (Pärnik *et al.*, 2014; Song *et al.*, 2010).

Comparing the transpiration (E) measurements, higher values were only registered for black alder (3.65 ± 0.45 in control plots and 4.57 ± 0.72 mol m⁻² s⁻¹ in treatment plots). In the rest of the cases in plots, where fertilizers have been applied, the measured

values were lower (for birch 3.56 ± 0.50 mol m⁻² s⁻¹ in control and 2.56 ± 0.46 mol m⁻² s⁻¹ in treatment plots, for hybrid alder the transpiration values were 4.09 ± 0.50, 3.99 ± 0.22 and 1.35 ± 0.02 mol m⁻² s⁻¹ in control, nitrogen treatment and wood ash/nitrogen treatment, respectively. For wild cherry, transpiration was registered only in control plots (2.14 ± 0.14 mol m⁻² s⁻¹). The comparison of the mean values of E and the calculated SEMs are shown in Figure 2. No general pattern was observed between fertilizer application and transpiration. Such factors as humidity, temperature and wind speed may have affected transpiration rates. Birches use water inefficiently and excessive

Table 2

Foliar nutrient content of fast-growing deciduous tree species and hybrids (mean values ± SEM)

Species	Fertilization regimen	N, g kg ⁻¹	P, g kg ⁻¹	Ca, g kg ⁻¹	Mg, g kg ⁻¹	K, g kg ⁻¹
Black alder	Control	38.0 ± 0.8	3.81 ± 0.67	11.68 ± 1.07	3.86 ± 0.19	14.37 ± 0.65
	NH ₄ NO ₃	38.12 ± 1.00	3.67 ± 0.17	9.97 ± 0.45	3.59 ± 0.15	13.40 ± 0.29
Silver birch	Control	39.47 ± 0.90	3.87 ± 0.29	7.09 ± 1.07	3.23 ± 0.21	10.21 ± 0.70
	NH ₄ NO ₃	37.42 ± 0.70	3.79 ± 0.11	7.37 ± 0.79	3.44 ± 0.13	10.08 ± 0.61
Hybrid alder	Control	37.50 ± 0.46	3.598 ± 0.12	9.95 ± 0.79	2.71 ± 0.28	13.35 ± 0.65
	NH ₄ NO ₃	39.71 ± 1.38	4.050 ± 0.20	10.38 ± 1.03	3.19 ± 0.23	13.98 ± 0.60
	NH ₄ NO ₃ + wood ash	35.77 ± 1.59	2.97 ± 0.09	9.89 ± 0.25	3.28 ± 0.23	13.62 ± 0.75
Hybrid aspen	Control	36.46 ± 1.64	4.84 ± 0.28	13.92 ± 2.16	3.97 ± 0.11	19.51 ± 0.99
	NH ₄ NO ₃	36.66 ± 1.24	4.56 ± 0.22	10.91 ± 1.01	3.57 ± 0.13	17.58 ± 0.47
Wild cherry	Control	34.50 ± 2.14	4.36 ± 0.28	14.47 ± 1.76	4.69 ± 0.19	16.29 ± 1.11
	NH ₄ NO ₃ + wood ash	37.56 ± 0.72	4.58 ± 0.65	19.95 ± 1.85	4.76 ± 0.14	18.22 ± 1.60

transpiration is characteristic to this species. In large trees daily transpiration is about 514 kg water per 1 kg foliage (OECD, 2006). Black alder is another water-demanding species, and their leaves lack a mechanism for transpiration control (Laessens, Oosterbaan, & Peter, 2010). Results show that birch, black alder and alder hybrids have the highest transpiration rates.

Although no statistically significant differences in foliar chemistry between control and fertilized plots were found when comparing the treatments, an increase in phosphorus concentration was observed for hybrid alder in case of ammonium nitrate addition. It was expected that wood ash application would avert phosphorus deficiency, resulting in higher photosynthetic activity; however, the contrary was observed for hybrid alder – in plots treated with wood ash, phosphorus concentration was the lowest among treatments. One of the possible explanations for increasing photosynthetic activity could be the role of trace elements in photosynthesis, whose levels might have increased after addition of wood ash. An overall increase in foliar nutrient content was observed for wild cherry; however, it did not result in photosynthetic activity increase. Foliar nutrient levels are summarized in Table 2.

No statistically significant correlations were found between leaf nitrogen, leaf carbon and soil parameters (total soil carbon, total soil nitrogen and pH);

however, the correlations in most cases were weakly to moderately positive. The increased soil nitrogen content is reflected in increased foliar nitrogen levels, indicating that nitrogen in soil exists in forms available to plants.

Conclusions

1. The study indicates that nitrogen addition may not result in increased photosynthetic activity. It is also possible that the photosynthetic activity has increased at canopy scale, not at leaf scale. Wood ash addition seems to have resulted in higher photosynthetic activity for hybrid alder, although it could not be explained with phosphorus availability. Levels of other nutrients may have increased after wood ash application.
2. Although the process is closely related to photosynthesis, no impact of fertilization on transpiration was observed. Environmental factors, such as humidity, temperature and wind speed may play a larger role in this process.

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AFFORESTATION OF ABANDONED PEAT EXTRACTION SITES WITH SCOTS PINE (*PINUS SYLVESTRIS* L.) AS A SOLUTION OF CLIMATE CHANGE MITIGATION

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Abstract

On a global scale, ambitious climate change mitigation targets are set. By 2050, the European Union is expected to be climate neutral which means that the greenhouse gas (GHG) emissions will not exceed removals. This initiative is also supported by Latvia. For businesses and carbon intensive industries transition to climate neutral economy will be provided by Just Transition Fund. The direction of the peat sector towards climate neutrality will promote research and innovation as well as restoration of peat extraction sites. These are also the objectives of implementing the Just Transition Fund for investments in Latvia. Studies on management of peat soils to improve the calculation of greenhouse gas (GHG) emissions have been carried out in Latvia within LIFE REstore project. The aim of the study is to assess the impact of afforestation of abandoned peat extraction sites with Scots pine (*Pinus sylvestris* L.) on GHG emissions compared to retaining of the existing situation (abandoned peatlands with poorly developed vegetation). Afforestation of degraded peatlands can contribute to significant GHG reduction in wetlands – up to 20% of the net GHG emissions due to wetlands management. The most of the GHG mitigation potential is ensured by accumulation of CO₂ in living biomass.

Key words: afforestation, greenhouse gas emissions, peat extraction sites, climate change.

Introduction

The role of wetlands as a carbon sink has become more important as they contribute to the greenhouse effect and climate change (Quinty & Rochefort, 2003). The important role of peatlands as carbon sinks has been demonstrated by carbon cycle studies (Bäders, 2011). Although natural bogs emit greenhouse gases such as methane, drainage of bogs and peat extraction lead to significant increase in global warming potential and the loss of carbon sinks that have been developed over thousands of years (Quinty & Rochefort, 2003; Kløve *et al.*, 2017). The amount of carbon stored in peatlands is closely related to the thickness of the remaining peat layer and the degree of decomposition of the peat, as well as humification processes in the peat (Bäders, 2011). Bogs are types of ecosystem where carbon, along with nitrogen and several other elements, have accumulated as peat formed from plant litter that accumulates in these areas. In the past, bogs covered 5–6% of the surface of continental Europe, half of the bogs in Europe are subject to various land uses, often associated with drainage (Drösler *et al.*, 2008). In Latvia, according to the data of the Peat Fund of 1980, the total area of bogs is 6401 km² or 9.9% of the country's territory. Peat resources play a significant role in both the conservation of biodiversity and its use in the economy (Jansons, 2016). In Latvia, peat was initially mined in quarries without draining the bogs. At the end of the 19th century and the most of the 20th century, peat was extracted in drained bogs. Today, many of these areas are already overgrown with forests or naturally revegetated. The use of peat generates GHG emissions from peat extraction in the peat extraction area and emissions from the use of peat in agriculture, such as forestry, forest plant

growing, horticulture, livestock litter, and energy from peat incineration. In the category of wetlands in the GHG inventory, emissions are calculated from peat extraction areas where peat extraction takes place or has taken place (ha) and the amount of peat extracted (t), distinguishing between agricultural and energy use (Cabinet of Ministers, 2020). In wetland category, changes in carbon stock are also calculated, in the areas with woody vegetation that do not meet the definition of forest land (living and non-living biomass) and GHG emissions from soils in areas renaturalized after peat extraction by purposefully restoring the original moisture regime or the areas, which were flooded. GHG emissions from wetlands in 2018 were 1708.92 kt CO₂ eq. (Skrebele *et al.*, 2020). It is important to reduce GHG emissions by avoiding the development of new peat deposits as much as possible, first of all, evaluating the possibility of peat extraction in historical peat extraction sites, where peat extraction no longer takes place, but recultivation is not performed (Cabinet of Ministers, 2020). Peat extraction no longer takes place in such areas, but these areas are not able to regenerate naturally as bogs or other ecosystem. In the cutaway peatlands, GHG emissions are even more negative in the context of GHG emissions without recultivation and the creation of new or expanded peat extraction sites (Priēde & Gancone, 2019). Evaluating the experience gained and accumulated in the peat extraction sector and literature, as well as information provided by industry specialists and experts, the types of recultivation suitable for Latvian conditions are: renaturalization, afforestation, berry plantations – blueberries and cranberries, cultivation of paludicultures – growing of bog plants for biomass production, creation of

water reservoirs and growing of perennial grasslands (Cabinet of Ministers, 2020; Priede & Gancone, 2019). Within the scope of the LIFE REstore project “Sustainable and responsible management and re-use of degraded peatlands in Latvia”, areas affected by peat extraction have been identified with a total area of about 50 thousand hectares, of which about 15 thousand ha are peat extraction (30%), about 17 thousand ha (34%) peat extraction has taken place or is undergoing reclamation (natural regeneration, flooding and flooded areas, forests, grasslands or berry plantations) and approximately 18 thousand ha (36%) are degraded areas subject to recultivation. In total, for 18 thousand ha of degraded, non-reclaimed peatland areas and the best suitable recultivation method for these areas has to be chosen (Priede & Gancone, 2019). The purpose of reclamation is to ensure the continued full use of mining sites after the completion of mining, to prevent threats to human life and health and the environment, and to promote integration into the landscape (Cabinet of Ministers, 2020). The types of recultivation of peat extraction sites that have been determined in a general way, in accordance with the regulatory enactments in force in Latvia, are renaturalization (restoration of the environment characteristic of a bog), preparation for agricultural use (berry plantations), preparation for use in forestry, creating water bodies for recreation (Cabinet of Ministers, 2012). Forests is the environment, where significant part of the organic matter is preserved in the form of peat for a long time. By mobilizing the energy stored in the peat layer, the productivity of wood increases several times, additional amounts of CO₂ are captured and accumulated in living biomass. Forests contribute to the reduction of the greenhouse effect by increasing the stock of wood, accumulating carbon and releasing the oxygen necessary for the existence of living organisms. Approximately 700,000 ha of forests out of 1.5 million ha of swampy and wet forests have been reclaimed in Latvia (Indriksons & Palejs, 2005; Zālītis, 2006). Most of the CO₂ emissions in Latvia are generated in organic soils, more than half of these emissions are formed in forest lands, but the emissions from soil due to wetland management are an important source of emissions, excluding GHG emissions from peat extraction (Priede & Gancone, 2019). Average GHG emissions and CO₂ removals depend on the climatic region and soils fertility. CO₂ and N₂O emissions from drained forest soils account for less than 10% of net emissions from forest stands, while CO₂ sequestration in living biomass accounts for 35% of total CO₂ sequestration in forest stands. According to the interpretation of the 2013 Supplement to the 2006 IPCC Guidelines, for all organic soils in Latvia the same emission factors have to be used, regardless of whether the area is drained

or not, which means that in terms of emissions, forest stands with drained and naturally wet soils have the same emission factors. CO₂ emissions from soil in forests on non-drained mineral soils and forests on drained organic soils are 2.6 tons of CO₂-C per year, direct N₂O emissions from soil are 2.8 kg N₂O-N ha⁻¹ per year (4.4 kg N₂O ha⁻¹ or 1.3 tons CO₂ eq.), CH₄ emissions from ditches are 217 kg CH₄ ha⁻¹ per year (Lazdiņš, 2015).

The most important measure to offset GHG emissions from deforestation is afforestation (Lazdiņš, 2015). Forestry is an advantageous opportunity for recultivation of developed peat deposits, as it has both commercial and aesthetic values. Relatively new recultivation practice is afforestation of peat deposits; therefore, we are still looking for the most suitable tree species for afforestation, as well as the most suitable fertilizers that would ensure successful recultivation of the developed peat deposits in the long term (Bebre & Lazdiņa, 2017). The most suitable tree species for afforestation of peat extraction sites are pine and birch (Liepiņš, Baders, & Liepa, 2009). Afforestation ensures the accumulation of CO₂ in living and non-living biomass, litter and soil (Progress report under..., 2017). According to studies in Finland and Sweden, CO₂ emissions from afforested peat deposits average 1397 g m⁻² per year (1008–1756 g m⁻² per year), CH₄ emissions are –0.05 g m⁻² per year (–0.03–0.09 g m⁻² per year) and N₂O emissions are 0.15 g m⁻² per year (0.02–0.75 g m⁻² per year) (Mhkiranta *et al.*, 2007; Alm *et al.*, 2007).

The average additional growth of a tree trunk during the rotation period using improved planting material in reforestation is 43 m³ ha⁻¹ (Progress report under..., 2017). In addition, the sequestration of CO₂ in living biomass using selected planting material in reforestation is on average 50 t ha⁻¹ in forest management cycle. The direct impact of the selected material on the Latvian scale can reach 104 million tons of CO₂ in 75 years or 138 Gg of CO₂ per year (Lazdiņš, 2015). Afforestation of developed peat deposits is a technically easily feasible practice and the main wood products are wood chips, pulpwood and roundwood (Makovskis *et al.*, 2019). In sustainable forestry, CO₂ sequestration is in balance with long-term forest growth, and felled timber from the forest can be seen as a substitute for natural extinction, which would otherwise be the same. Growing trees act as a carbon sequestration system, providing physical storage of carbon that was previously released into the atmosphere (Pingoud *et al.*, 2003; Sathre & O’Connor, 2010). In managed forests, carbon is retained in the resulting building materials and furniture, and the use of wood as a fuel saves the use of fossil fuels and thus eliminates additional CO₂ emissions (Kļaviņš & Zaļoksnis, 2016).

Wood products have been identified as a significant source of CO₂ removals, but may be affected by reduced logging or a deterioration in the structure of the timber being harvested (higher proportion of biofuels), as this carbon sink may become a significant source of CO₂ emissions in the future (Lazdiņš, 2015). Wood products reduce CO₂ emissions because wood products are carbon sinks and can replace carbon-intensive materials. Each cubic meter of wood captures 0.9 t of CO₂, which is not released into the atmosphere during the initial life cycle of wood products, as well as after the wood products are recycled and reused (Pingoud *et al.*, 2003). Each cubic meter of wood used to replace other building materials reduces CO₂ emissions to the atmosphere by an average of 1.1 t of CO₂, plus 0.9 t of CO₂ accumulated in wood, then a total of 2 t of each cubic meter of wood (Beijere *et al.*, 2006).

The aim of the study is to assess the impact of afforestation of abandoned peat extraction sites with Scots pine (*Pinus sylvestris* L.) on GHG emissions compared to retaining of the existing situation (abandoned peatlands with poorly developed vegetation).

Materials and Methods

During the LIFE REstore project “Sustainable and responsible management and re-use of degraded peatlands in Latvia” research work was carried out to replace the emission factors offered by Guidelines of GHG Inventories of Intergovernmental Panel on Climate Change (IPCC) with nationally applicable emission factors and activity data. Ecosystem carbon dioxide (CO₂) exchange – measurements were taken, using transparent chamber method, which enables determination of the CO₂ removals caused by photosynthetic activity of ground vegetation (Salm *et al.*, 2012) and the opaque chamber method for determination of CH₄ and N₂O fluxes (Hutchinson & Livingston, 1993). Gas samples were collected in 50 ml glass flasks previously vacuumed in the lab. Gas analyses were done using a gas chromatography method. CO₂ fluxes in transparent chamber were determined using EGM-5 analyser. Results of gas analyses were subjected to quality control, by verifying if changes of gas concentrations are linear during 60 min. period (samples were taken 4 times with 20 min. interval at each sampling cycle using opaque chambers). Low quality data series (R² value of 4 measurements is below 0.95 for CO₂) are excluded from further analysis. Litter input and fine root production was estimated using literature data (Neumann *et al.*, 2019).

In Latvia, about 18 thousand ha of abandoned cutaway peatlands, where peat extraction has been ceased or completed, but no reclamation has been

carried out, are identified within the LIFE REstore project. Afforestation with Scots pine *Pinus sylvestris* L. is one of the best after-use scenarios to maximize climate change mitigation effect. For GHG emission reduction calculation nationally applicable emission factors elaborated in LIFE REstore project (CH₄, CO₂ and N₂O) and default emission factors for temperate moist climate zone according to IPCC 2014 Wetlands supplement (dissolved organic carbon, proportion of ditches and CH₄ from ditches) are used. For peat extraction site afforested with conifers, average net CO₂ emissions are equal to 0.96 t CO₂-C ha⁻¹ annually, dissolved organic carbon (DOC) 0.31 t C ha⁻¹ annually, CH₄ emissions are 22.39 kg CH₄ ha⁻¹ annually, CH₄ emissions from drainage ditches are 217 kg CH₄ ha⁻¹ annually and N₂O emissions are -0.05 kg N₂O-N ha⁻¹ annually. If peat extraction still continues, net emissions are equal to 1.09 t CO₂-C ha⁻¹ annually, DOC 0.31 t C ha⁻¹ annually, CH₄ emissions are 10.83 kg CH₄ ha⁻¹ annually, CH₄ emissions from drainage ditches are 542 kg CH₄ ha⁻¹ annually and N₂O emissions are 0.44 kg N₂O-N ha⁻¹ annually. In abandoned peat extraction fields that are not covered with vegetation (alternative scenario to compare impact of the afforestation scenario) 0.95 t CO₂-C ha⁻¹ annually, DOC 0.31 t C ha⁻¹ annually, CH₄ emissions are 1.42 kg CH₄ ha⁻¹ annually, CH₄ emissions from drainage ditches are 542 kg CH₄ ha⁻¹ and N₂O emissions are 0.11 kg N₂O-N ha⁻¹ annually. In abandoned peat extraction fields covered with vegetation that is not a tree stand CO₂ emissions are 1.85 t CO₂-C ha⁻¹ annually, DOC 0.31 t C ha⁻¹ annually, CH₄ emissions are 28.39 kg CH₄ ha⁻¹ annually, CH₄ emissions from drainage ditches are 217 kg CH₄ ha⁻¹ and N₂O emissions are 0.04 kg N₂O-N ha⁻¹ annually (Priede & Gancone, 2019).

GHG emission reduction potential was estimated by comparison of soil GHG fluxes and carbon stock changes in case of afforestation of the abandoned peatlands and retaining of existing situation (abandoned peatland with poorly developed vegetation). Calculation period is 30 years to demonstrate GHG mitigation potential, which can be reached in 2050 by quick implementation of the afforestation measures in abandoned peatlands.

Results and Discussion

The GHG emission factors according to IPCC 2014 Wetlands supplement and LIFE Restore results applied in the calculation are provided in Figure 1.

In 18 thousand hectares (kha) abandoned peatlands with poorly developed vegetation, GHG emissions from soil according to IPCC 2014 Wetlands Supplement are the following, CO₂ emissions from soil are 171.6 kilotonnes (kt) CO₂ eq. yr⁻¹, DOC 20.5 kt CO₂ eq. yr⁻¹, CH₄ emissions are 1.1 kt CO₂

eq. yr⁻¹ and N₂O emissions are 23.6 kt CO₂ eq. yr⁻¹. Total GHG emissions from soil in case of continued abandonment of these areas are 216.8 kt CO₂ eq. yr⁻¹. According to the emission factors elaborated within the scope of the LIFE REstore project CO₂ emissions in 18 kha are 122.1 kt CO₂ eq. yr⁻¹, DOC 20.5 kt CO₂ eq. yr⁻¹, CH₄ emissions are 12.8 kt CO₂ eq. yr⁻¹ and N₂O emissions are 0.4 kt CO₂ eq. yr⁻¹. Total GHG emissions from soil are 155.7 kt CO₂ eq. yr⁻¹. Application of country specific GHG emissions factors reduces GHG emissions by 28%.

If 18 kha of abandoned peatlands are afforested with Scots pine (*Pinus sylvestris* L.) GHG emissions from soil according to IPCC 2014 Wetlands supplement, CO₂ emissions from soil are 171.6 kt CO₂ eq. yr⁻¹, DOC 20.46 kt CO₂ eq. yr⁻¹, CH₄ emissions are 1.09 kt CO₂ eq. yr⁻¹, CH₄ emissions from drainage ditches are 2.44 kt CO₂ eq. yr⁻¹ and N₂O emissions are 23.60 kt CO₂ eq. yr⁻¹. Total GHG emissions from soil are 219.19 kt CO₂ eq. yr⁻¹. According to country specific emission factors in 18 thousand ha, CO₂ emissions are 63.5 kt CO₂ eq. yr⁻¹, DOC 20.46 kt CO₂ eq. yr⁻¹, CH₄ emissions are 9.82 kt CO₂ eq. yr⁻¹, CH₄ emissions from drainage ditches are 2.44 kt CO₂ eq. yr⁻¹ and N₂O emissions are -0.40 kt CO₂ eq. yr⁻¹. Total GHG emissions from soil if country specific emission factors are applied, reduces to 95.47 kt CO₂ eq. yr⁻¹ (by 56%). After afforestation carbon stock in living woody biomass increases to 93 t C ha⁻¹, in dead wood – to 4.50 t C ha⁻¹ in 30 years period and in ground biomass – to 2.00 t C ha⁻¹ during 5 years period. These values are used in national GHG inventory to determine impact of land use changes.

Reduction of CH₄ emissions from soil following to the afforestation according to IPCC 2014 Wetlands Supplement is 0.02 kt CO₂ eq. yr⁻¹ and reduction of

CH₄ emissions from drainage ditches -2.44 kt CO₂ eq. yr⁻¹. Total GHG emission reduction from soil after afforestation is negative according to IPCC 2014 Wetlands Supplement -2.41 kt CO₂ eq. yr⁻¹. According to the country specific emission factors, the reduction of CO₂ emissions from soil after afforestation is 58.91 kt CO₂ eq. yr⁻¹, reduction of CH₄ emissions is negative, including -4.9 kt CO₂ eq. yr⁻¹ in forest area and -2.44 kt CO₂ eq. yr⁻¹ from drainage ditches and reduction of N₂O emissions is 0.77 kt CO₂ eq. yr⁻¹. Total GHG emission reduction from soil after afforestation, if the country specific emission factors are applied, is 60.20 kt CO₂ eq. yr⁻¹. The difference between the default assumptions and country specific method is 14.1 kt CO₂ eq. yr⁻¹. Additional reduction of GHG emissions is ensured by removals of CO₂ in living and dead biomass in forest lands – 9.2 tons CO₂ ha⁻¹ yr⁻¹. The net GHG emission reduction does not significantly differ in case of application of the IPCC 2014 Wetlands supplement and country specific emissions factors; in 30 years period it reaches 5000 kt CO₂ eq. (167 kt CO₂ eq yr⁻¹). However, the lack of difference is mainly due to significant contribution of living biomass in the estimation of the GHG emission reduction, which is the same in both scenarios (Figure 2).

In spite of similar values of GHG emission reduction due to afforestation, the absolute values of the emission factors elaborated by the LIFE Restore project team is about twice smaller than the default ones, which means that the GHG emissions from soil in abandoned peatlands and forest lands are significantly overestimated. Emission factors elaborated by the LIFE Restore project have also significantly smaller uncertainty range 30–80% instead of 90%, and they are better adopted to country specific activity data.

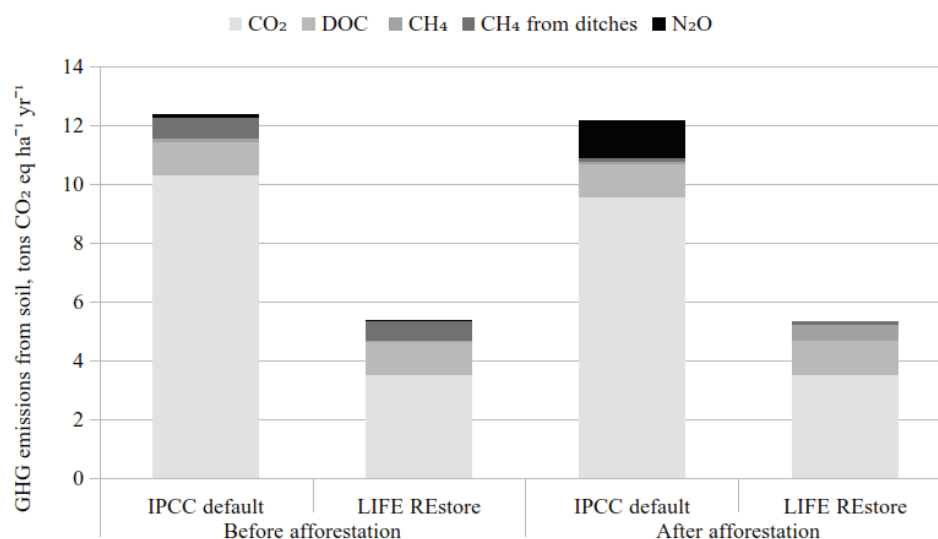


Figure 1. The average annual GHG emissions from soil in afforested area and abandoned peatland.

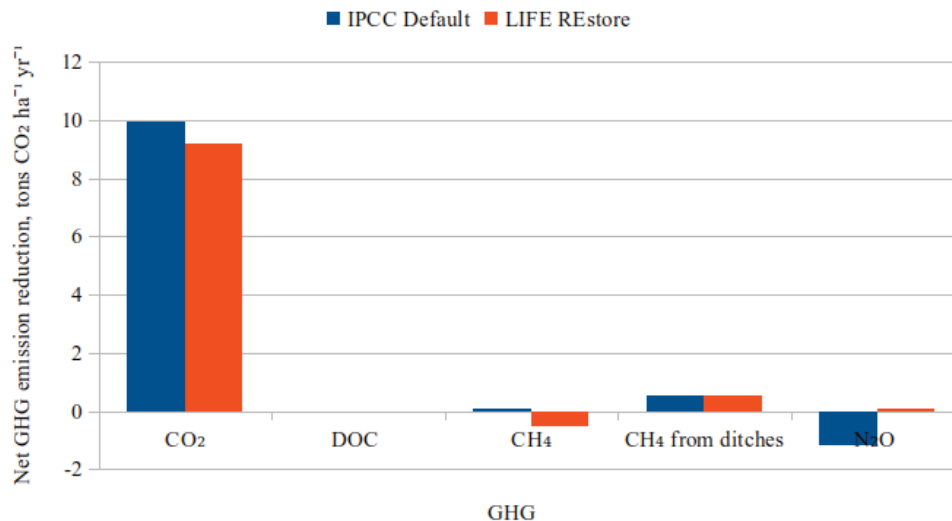


Figure 2. The average annual GHG emission reduction due to afforestation in a 30-year period.

Conclusions

Afforestation of degraded peatlands can contribute to significant GHG reduction in wetlands – up to 20% of the net GHG emissions due to wetlands management. The most of the GHG mitigation potential is ensured by accumulation of CO₂ in living biomass.

Despite the fact that the elaborated emission factors are within the range of uncertainty of the default emission factors provided in the IPCC 2014 Wetlands supplement, application of country specific emission factors is important. They increase accuracy and turn the net increase of GHG emissions from soil due to afforestation, if the default emission factors by the Wetlands supplement are applied, into net removals, if the country specific factors are applied.

Increase of accuracy of the emission factors is also important, because the value and sign of different GHGs is changing – CH₄ turns into net source of emissions and value of N₂O and CO₂ reduces, which points to the conclusion that the default emission factors reflect different conditions (water regime, soil fertility) in comparison to Latvia.

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WINTER FROST DAMAGE AND ITS LINK TO EARLY GROWTH AND SURVIVAL IN A POPLAR CLONE COLLECTION

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Abstract

The Northern European countries largely rely on poplars and their hybrids that are transferred northward from more southern regions, therefore, facing a trade-off between the use of full growth potential and sufficient tolerance of low temperatures. We characterized frost damage and its link to early growth and survival of 33 poplar genotypes at the age of one, three, and four years in a clonal collection on agricultural land. The survival after the first season varied from 42% to 99%. Half of the clones had autumn frost injuries with a maximum of 20% of trees damaged. The autumn frost-damaged trees were significantly ($p < 0.001$) higher before the injury than the undamaged trees with site mean 105.3 ± 7.9 and 72.0 ± 2.5 cm, respectively, but, at the clone mean level, the proportion of autumn frost-damaged trees had no link to survival ($\rho = 0.53$, $p < 0.001$). The observed winter frost damage showed no relation ($p < 0.05$) regarding the proportion of trees with autumn frost damage. Trees with winter frost damage tended to be shorter than undamaged trees ($p < 0.001$) and had lower survival ($\rho = 0.47$, $p < 0.01$). The maximum height difference of the clones among the studied years was in a magnitude from 2.4 to 2.9, and the stability of a clonal ranking increased with the age. The results emphasize the need for further monitoring of the clone performance under the local climatic conditions before recommendations of commercial use of particular clones in Latvia.

Key words: Clonal ranking, cold injury, maladaptation, *Populus* hybrids.

Introduction

Traditional forestry is facing challenges to satisfy expanding global demand for the production of raw materials from sustainable, renewable natural resources. Roundwood and bioenergy production by fast-growing species outside the natural forests pose the potential to produce substantial yield on the limited land area (Jürgensen, Kollert, & Lebedys, 2014; Mola-Yudego *et al.*, 2017). This allows to efficiently preserve sequestered CO₂ and substitute fossil fuels thereby mitigating climate change (Sulaiman, Abdul-Rahim, & Ofozor, 2020) and reducing the pressure on natural forests (Pawson *et al.*, 2013) that might be not very efficient in providing this ecosystem service (Kēniņa *et al.*, 2018, 2019a, 2019b).

Species and hybrids of the *Populus* genus are shown to be among the most promising fast-growing tree species in the boreal and hemiboreal region (Rytter *et al.*, 2013) with a mean annual increment of up to 20 m³ ha⁻¹ year⁻¹ in a rotation of 25 years (Rytter & Stener, 2014). Besides, the assessed species had demonstrated notable resistance to main damaging agent in Northern Europe - wind (Čakša *et al.*, 2021; Samariks *et al.*, 2020, 2021). The plantation productivity primarily depends on the performance of selected genotypes. Although poplars represent a rather wide genetic basis and are easy to vegetatively propagate, in comparison to other species (Gailis *et al.*, 2021), there is very limited adapted planting stock available in Europe. Large areas are established using exclusively a few superior clones, such as OP42 in Denmark (Stener & Westin, 2017) and Sweden (Karacic *et al.*, 2020) and I-214 in southern Europe (FAO, 2016), posing concerns related to climate change and pest or disease resistance. Currently, there is a breeding program for

poplars and 16 clones already selected and tested for commercial use in Sweden (Stener & Westin, 2017). Other countries in the north of Europe fully rely on material that is bred and imported from more southern regions, mainly Italy and Germany (Niemczyk *et al.*, 2018). The northward transfer, however, might result in a trade-off between the use of full growth potential and sufficient frost tolerance. Too early or late growth onset and cessation leads to suboptimally used growing season (Jansons *et al.*, 2014; Gailis *et al.*, 2019; Skrøppa & Magnussen, 1993; Zeltiņš *et al.*, 2019), meanwhile increasing the risk of cold injuries (Howe *et al.*, 2000; Junttila & Kaurin, 1990). Injuries might be affected both by genotype (clone) and growth rate (Šēnhofa *et al.*, 2016; Zeltiņš *et al.*, 2016). Additionally, crossbreeding alters genotypically controlled adaptive traits of a parental species and hybrids from different regions (Gudynaitė-Franckevičienė, Pliūra, & Suchockas, 2020), hence, imposing the importance of genotype testing under local conditions before their application at a commercial scale (Jansons *et al.*, 2018; Lazdiņa *et al.*, 2016, Senhofa *et al.*, 2017; Pliūra *et al.*, 2014).

This study aimed to characterize susceptibility to frost and its link to early growth and survival of 33 poplar genotypes with a different source of origin for the first four years in a clonal collection on agricultural land. We intended to assess their early performance under low agricultural impact.

Materials and Methods

The study was carried out in a clonal collection in Kalsnava (56°41' N, 25°58' E), Latvia, established on abandoned agricultural land (heavy stony clay soil) in the spring 2016. In total, 34 poplar clones from

the *Aigeiros* and *Tacamahaca* sections of the genus *Populus* were represented. Subsets of the clones have Swedish, Italian, and German origin, and together with the clone OP42 (synonym Hybride275 for the same clone), they have been introduced recently, during the last 10 to 15 years. The collection also includes clones collected across Latvia. These are progenies (cuttings) of the poplars that survived after introduction, presumably, in the 1960s, but the origin of these clones is unknown. Per each clone, 97 to 102 cuttings (about 25 cm length) were planted in narrow spacing mono-clonal rows with 350 cm between the rows and 50 cm between individual plants in a row (that makes up 5,714 trees per ha) with no replications within a small area. The site was prepared by inverted soil scarification before the planting but thereafter received minimal agricultural impact with exception of weed control by rotary brush hog mower between tree rows. The plantation was fenced.

In the spring 2017, tree survival and damage (autumn frost injuries, browsing damage, dead or undamaged) were assessed, and the height of all living trees was measured (except for Clone OP42). All trees had developed only a single stem.

In the spring 2018, winter frost damage was assessed. Clones were visually evaluated on a five-scale grade: 0 – dead, 1 – severe damage, 2 – mild damage, tree recovers, 3 – minor damage, and 4 – no visible winter frost damage.

In the spring 2019, the height of all live trees was measured. In the spring 2020, the height was measured for every second tree in a row.

The normality of data was assessed by the Shapiro–Wilk test. The differences in height among the clones and their origins were assessed by nonparametric Kruskal-Wallis, followed by the Dunn test for pairwise comparisons. Mann-Witney U test was used for pairwise clone height comparison for damaged and undamaged trees. Relations between tree and clone parameters were assessed by Spearman's rank correlation. All tests were performed in R (version 4.0.2), at $\alpha = 0.05$. Mean values \pm 95% confidence interval are showed throughout the paper.

Results and Discussion

Tree survival after the first season was 82% (site mean), and varied from 42% for clone AF18 to 99% for clones Max1 and Max3 (Figure 1). The average survival of the clonal collection was similar or higher than was found in trials on agricultural land in Denmark at the age of three and Southern Sweden at the age of four years (52 to 89%) for a clonal set that partly overlapped with our study (Stener & Westin, 2017). However, several clones had more than one-third of cuttings dead already after the first growing season. The design of a clonal collection might pose risks of

low survival due to microclimatic differences as there was only one replication per clone. However, the studied site was a flat and homogeneous field and no pattern in the spatial distribution of low high mortality was present, suggesting that the microclimatic differences are unlikely to be a cause of mortality.

A high proportion of trees was browsed (site mean 59%). The damage was present for all clones and occurred in the winter when a fence was accidentally left unlocked allowing access for wild ungulates. Browsing is a widespread problem in *Populus* plantations that might contribute to low vitality and hence increase mortality. However, not all *Populus* clones are browsed to the same extent: the proportion of damaged trees varied from 16% to 91%, and 24 out of 33 clones had more than half of the trees browsed. Several feeding experiments have confirmed underlying differences in preference of clones due to plant macronutrient and mineral content (Holeski *et al.*, 2016) and phytochemical defences (Lastra, Kenkel, & Daayf, 2017).

Results at the beginning of the second growing season revealed that several clones might be sensitive to the local climate as half of the clones (16 out of 33) had cold injuries at the beginning of the second growing season. An inappropriate adaptation is a common concern for the low survival of introduced clones (Gudynaitė-Franckevičienė, Pliūra, & Suchockas, 2020; Karacic *et al.*, 2020; Schreiber *et al.*, 2013). The differences in autumn frost damage are likely related to clonal differences in the timing of bud set (Friedman *et al.*, 2008; Howe *et al.*, 2000) that is typically found to be highly heritable (Pliūra *et al.*, 2014), thus, differ among the genotypes.

Indeed, while most of the clones were damaged scarcely (median of the proportion of damaged trees 4%), genotypes of certain families were more susceptible to sudden temperature drop than others. In our site progenies of *P. maximowiczii* \times *P. trichocarpa* had suffered from autumn frost substantially more than other clones with the proportion of damaged trees 12% for Hybride275, 14% for Matrix24, and 20% for Matrix11. However, while maladaptation might be related to the high mortality of northward-transferred clones, it seems an incongruous explanation for the high mortality of locally collected clone Pop1. The ortet of this clone was introduced in Latvia decades ago and has shown reasonable growth to be selected for progeny testing; therefore, presumably it should not be severely negatively affected by local climatic conditions.

Neither browsing, nor autumn frost damage was negatively related to survival ($\rho = -0.02$, $p > 0.05$ and $\rho = 0.53$, $p < 0.001$). However, only one-fifth (site mean 21%) of trees were alive and undamaged after the first growing season. Clones P0114 and

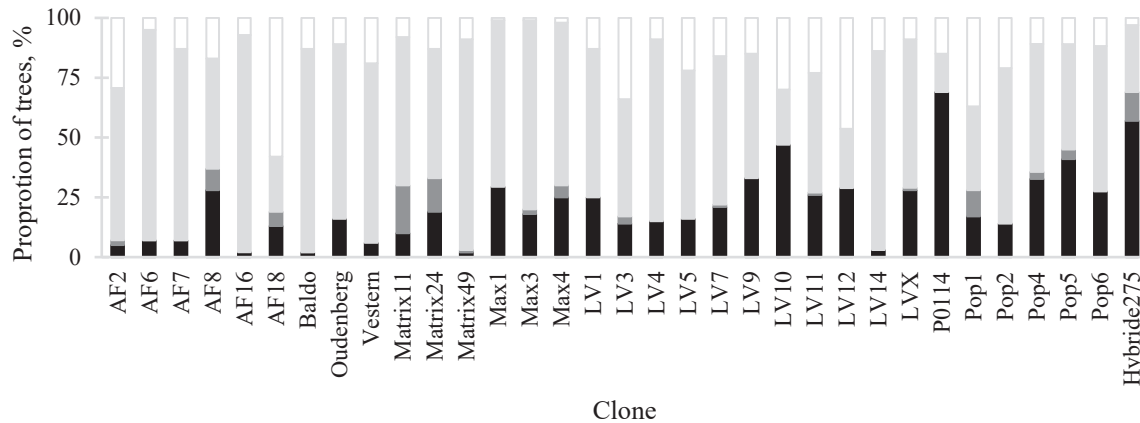


Figure 1. The damage of clones after the first growing season. Colour of the stacked bars: black – undamaged trees, dark grey – autumn frost-damaged trees, light grey – browsed trees, white – dead trees.

Hybride275 had a notably higher proportion (69% and 57%, respectively) of undamaged trees than the others, whereas eight of the clones had less than 10% of such trees.

There was no link between autumn frost damage and survival, suggesting that autumn frost damages unhardened shoots but not to an extent that affects plant survival. However, the effect of frost injuries depends on the timing and severity of frost and might be more severe in case of a more extreme temperature drop. This was shown in a recent study of simulated spring frost where 40% mortality of *P. maximowiczii* × *P. trichocarpa* hybrids and 45% mortality of *P. deltoides* × *P. trichocarpa* hybrids was observed for two-year-old trees (Gudynaitė-Franckevičienė, Pliūra, & Suchockas, 2020).

Tree survival showed a significant positive link to height ($\rho = 0.67$, $p < 0.001$). At the clone mean level, there was no relationship between height and proportion of autumn frost-damaged ($\rho = 0.42$, $p > 0.05$) trees. However, the autumn frost-damaged and browsed trees were significantly (both $p < 0.001$) higher than the undamaged trees with site mean 105.3 ± 7.9 , 83.0 ± 1.2 , and 72.0 ± 2.5 cm, respectively. The autumn frost-damaged trees were markedly longer compared to the intact trees, suggesting that fast-growing trees are more susceptible to frost at the end of the growing season. It is consistent with previous findings of trees that set buds later are higher, yet, also more prone to frost injuries (Pliūra *et al.*, 2014). Although we lack repeated assessment of damaged trees, autumn damage might cause stem quality defects due to disrupted apical growth and reduce tree height due to withered shoot top. A study of simulated spring frost showed height reduction by 26% for two-year-old poplars (Gudynaitė-Franckevičienė, Pliūra, & Suchockas, 2020), whereas a study in northern boreal conditions has shown height reduction to exceed 1.35 m length for poor-performing clones while no

or minor reduction for high- and average-performing clones at the age of three years (Schreiber *et al.*, 2013).

Overall, the observed damage had a low effect on clone height performance, as there was a relatively tight correlation between the height of the alive trees (pooled undamaged, autumn frost-damaged, and browsed trees) and undamaged trees ($\rho = 0.82$, $p < 0.001$). Clones significantly ($p < 0.001$) differed in their height after the first growing season, and their height was from 51 ± 8 to 124 ± 5 cm for alive trees (Figure 2), and 37 ± 9 to 159 ± 25 cm for undamaged trees. However, for a few clones damage significantly affected height: for clone AF16 undamaged trees had by 28% shorter height when all live trees were considered, whereas for clone LV3 undamaged trees were by 39% higher than all live trees.

Poplars in boreal conditions have to deal not only with the mismatching length of the growing season but also with low minimum temperatures and freeze-thaw events (Schreiber *et al.*, 2013). The clone survival after the first growing season was positively related to survival ($\rho = 0.80$, $p < 0.001$) at the age of three years. However, the observed winter frost damage showed no relation regarding the proportion of trees with autumn frost damage observed at the age of one year (Figure 3), indicating different underlying mechanisms for these types of injuries and implications for clone selection. As opposed to results of autumn frost injuries, trees with winter frost damage tended to be shorter than trees with no visible damage (Figure 4) and had lower survival ($\rho = 0.47$, $p < 0.01$). Such a trend of clones with low survival to be shorter was observed in boreal Canada and was linked to structural traits of wood, namely, xylem vessel size that also affects tree cold tolerance (Schreiber *et al.*, 2013).

The clonal differences in their height were significant at all studied ages (all $p < 0.001$; Figure 2). Our results of clonal mean at the respective age are in

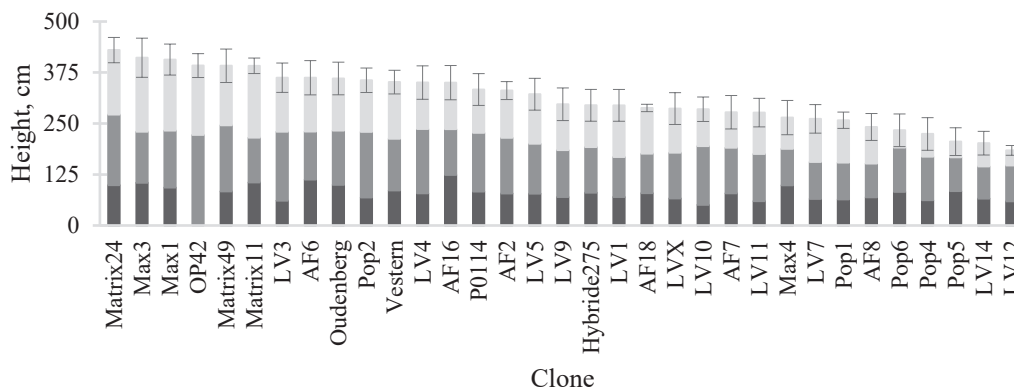


Figure 2. Height at the age of one (dark stacked bars), three (grey stacked bars), and four (light stacked bars; ± 95% confidence interval) years, survival (black bullets) at the age of three years and proportion of autumn frost-damaged trees (white bullets) at the beginning of the second growing season.

a range of mean height of the clone origin groups at the age of three years (166 to 258 cm) in Denmark and the age of four years (32 to 630 cm) in Sweden (Stener & Westin, 2017). Higher height growth was observed in north-eastern Germany (Landgraf, Carl, & Neupert, 2020), where 11 clones overlapped with our studied site. After the first growing season clones had height from 1.09 m to 2.35 m, notably exceeding height performance in our site already after the first season and the difference in height between the studies was even more distant at the age of three years.

The height difference between the highest and lowest clone increased from a magnitude of 2.4 at the age of one year to 2.9 at the age of three years, and such variation across the clones is typically observed in clonal trials (Nielsen *et al.*, 2014; Pliura *et al.*, 2007, 2014). During these two years, clones had moderately

changed their ranking of height (correlation between height measurements $\rho = 0.61$, $p < 0.001$; Figure 5a). Variation in ranking at the first few years is related to different growth development strategies, such as to clone ability to establish roots (Zalesny, Riemenschneider, & Hall, 2005; Zhao *et al.*, 2014) and allometric differences (Karacic *et al.*, 2020) that are determined by clone parental species. Poor or even adverse relation between height growth at the age of one and four years for 37 poplar clones was observed by Stener and Westin (2017). At the age of four years, the difference in height between the highest and lowest clone was slightly decreased. Additionally, the clonal ranking between the age of three and four years was changed less (maximal difference: 20 positions for clone LV3; Figure 5a) than between one and three years (maximal difference: 10 positions for clone Pop6; Figure 5b).

The poplar performance is also affected by genotype × environment interaction (Pliura *et al.*, 2007), which implies a need for clonal testing in

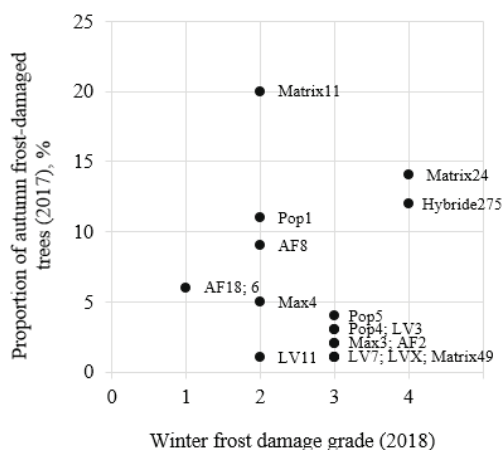


Figure 3. The proportion of autumn frost-damaged trees in the spring 2017 and the winter frost damage grade of the winter 2018. The grades of winter frost damage are as follows: 0 – dead, 1 – severe damage, 2 – mild damage, tree recovers, 3 – minor damage, and 4 – no visible winter frost damage.

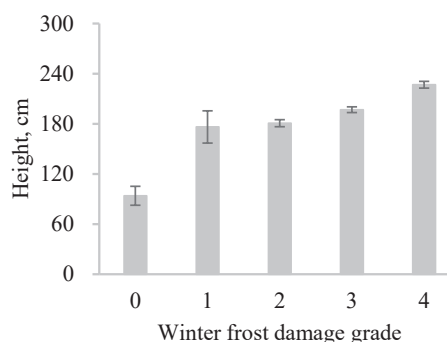


Figure 4. Tree height at the age of three years according to winter frost damage grades of the winter 2018. The grades of winter frost damage are as follows: 0 – dead, 1 – severe damage, 2 – mild damage, tree recovers, 3 – minor damage, and 4 – no visible winter frost damage.

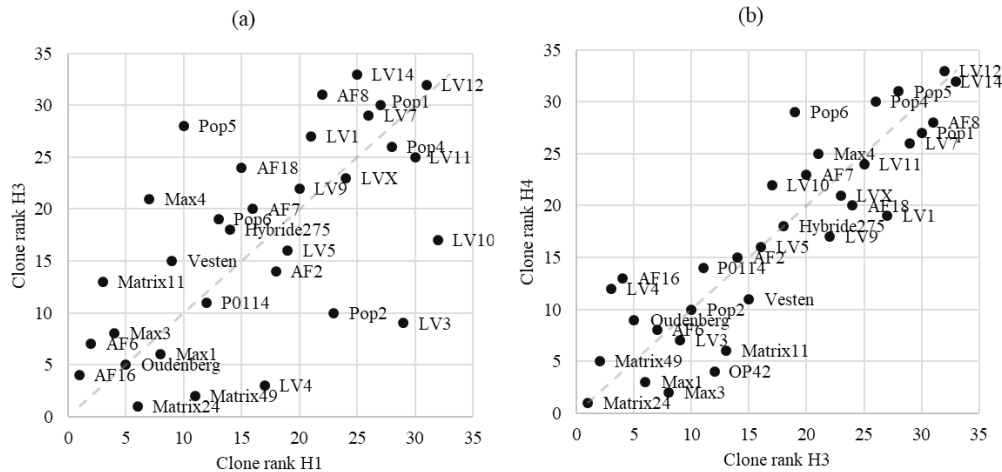


Figure 5. The changes in clone ranking for height (a) between the age of one (H1) and three years (H3) and (b) between the age of three (H3) and four (H4) years. The dashed lines represent the unchanged position of a rank between the different ages. Clones above the line have decreased rank and clones below the line have increased the rank.

various sites also for clones with decent growth. As an example, the clone OP42 was among the best performing clones for height and had reasonable survival in the present study, while in a study of clone OP42 on a frost-prone site all trees had completely withered stems in the spring after the first winter season (Šēnhofa *et al.*, 2017). On the other hand, the survival after the winter frost for clone Baldo (*P. deltoides*) was so severe that we removed it from the further measurements. This clone had shown inferior growth also in previous trials in Latvia (Šēnhofa *et al.*, 2018), suggesting that further testing and practical use of this particular clone might be inexpedient.

Our results indicate that clones with comparable height growth that are not susceptible to cold injuries might be selected (e.g. clones Max1, Matrix49; Figure 2). Alternatively, for clones Matrix24 and Matrix11, the fast-growth likely compensated the height-loss due to autumn frost damage, as these were among the highest clones at the age of four years. Progenies of the same parental species as clone series Matrix (*P. maximowiczii* × *P. trichocarpa*) have shown similar results by remaining position among the tallest clones regardless of significant height loss due to stem withering (Gudynaitė-Franckevičienė, Pliūra, & Suchockas, 2020). The prevalence of benefits over potential losses in growth and survival due to frost damage was observed for ten-year-old *P. tremuloides* clones that were moved as much as 7° latitude in western Canada (Schreiber *et al.*, 2013).

Alternatively, our results also agree with findings from a previous study (Lazdiņa *et al.*, 2016), suggesting that suitable tolerance to cold injuries of locally collected clones has not sufficient advantage to gain a higher yield, as compared to highly productive,

although more sensitive, introduced clones. Attempts to obtain local planting material are also done in the Czech Republic (Novotná, Štochlová, & Benetka, 2020). They tested locally selected *P. nigra* genotypes and crossings among their plus trees selected from natural populations with introduced clone Max4 over three rotations, each by three years. Similarly to our results, locally selected clones were inferior, and the best performing local clone had by the quarter lower yield of dry matter than clone Max4 (Novotná, Štochlová, & Benetka, 2020). The results from a trial in Sweden where 34 clones of different origin were tested showed the most popular ‘old’ clone in the region, OP42, to exceed growth performance by 30% to 60% at the age of 12 years of other more recently bred varieties (Karacic *et al.*, 2020).

Conclusions

The results of this study emphasize the need for clonal testing under the local climatic conditions before recommendations of particular clones for commercial use in Latvia. The results indicate that fast-growing trees (unhardened shoots) are more susceptible to autumn frost damage that reduces height, while trees with poor growth are more likely to be damaged by winter frost that affects survival. Regardless of the large variation among the clones, the best 15% of clones showed comparable height growth (difference less than 10%) and reasonable survival, suggesting that several clones with close performance could be selected for commercial use to mitigate both ecological and financial risks. Yet, further monitoring of the clone performance is needed for recommendations to use particular clones at least until they have reached half of the expected rotation age.

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REVIEW: CURRENT TRENDS IN OAT PROTEIN RECOVERY AND UTILIZATION IN AQUEOUS FOOD SYSTEMS

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Abstract

Oat protein itself, as a substance, has extensively been studied providing information on its nutritional value, some functional properties and possible applicability in food systems. Chosen protein isolation methods and technological aspects define final composition of obtained oat protein product, its concentration, nutrition value and its functionality in food industry. Scientific data on oat protein recovery methods, typically relying on protein solubility or dry fractionation, provides an insufficient knowledge about the success in commercialization of oat protein recovery technologies and their derivatives in form of oat protein. The aim of the study was to analyse and summarize the research findings on oat protein extraction methods and functional properties of oat protein. Semi-systematic, monographic methods were used to analyse the oat protein isolation techniques, functional properties of oat protein in aqueous food systems, covering the latest information on oat protein extraction methods. Wet and dry isolation methods were demonstrated as main methods in oat protein extraction. Functional properties of oat protein, such as thermal stability, solubility, emulsification, water hydration capacity and foaming were reviewed and evaluated, identifying limitations and protein alterations which occur through the oat protein extraction process. The study provides recent trends in oat protein recovery technologies, along with an overview of current and potential oat protein utilization in food systems.

Key words: oat protein, functionality, recovery, isolation, trends.

Introduction

Protein is an essential element for existence of living beings. It is responsible for proper growth and maintenance of body's inherent nitrogenous compounds. Delivering the sufficient amount of protein for metabolic demand which is expected to be utilized at a high efficiency is one of the primary's task in food supply systems. Among the many available protein sources, plant protein is the most important. The plant origin protein consumed in food counts at least 60% (Kawakatsu & Takaiwa, 2017; Krishnan & Coe, 2001). The cereal protein as a class predominates, counting about 40% of protein consumed in the world (Kawakatsu & Takaiwa, 2017). Typically, the protein of most cereals classified by Osborne fractionation method are alcohol-soluble prolamines (Walburg & Larkins, 1983). High content of glutamic acid, glutamine and proline inherent to cultivars *Triticaceae* stimulate the induction of the Celiac disease (Wieser, 2001). Oats (*Avena sativa*) along with rice (*Oryza sativa*) are the exception. Main amount of protein in these seeds is stored mainly as globulin (Shewry, Napier, & Tatham, 1995) which amino acid profile is typically more valuable when compared to glutelin rich crops such as wheat (*Triticum aestivum*) or corn (*Zea mays*). Amino acid composition of oat globulin demonstrate similarity to soy (*Glycine max*) glycinin. Exceptions were observed for tyrosine and phenylalanine which were higher in oat globulin and aspartic acid, proline, lysine those were lower (Brinegar & Peterson, 1982).

Despite being positively valued, the oat protein is not widely available, especially in concentrated form.

Moreover, protein isolation methods directly influence protein functional properties which subsequently impact protein applicability in food systems.

The aim of the study is to review the research findings on oat protein extraction methods and functional properties of oat protein.

Materials and Methods

Scientific databases Scopus and Web of Science were studied with the aim to cover available oat protein formation, extraction methods and oat protein functionality in aqueous food systems. Free sources available on the Internet, including but not limited to patents, companies web pages, fundamental documents, theses related to oat protein extraction methods and technologies, oat protein application and future trends were studied to analyze and summarize the information. Semi-systematic, monographic methods were used in the study.

Results and Discussion

Oat protein is typically recovered applying dry or wet fractionating methods discussed below. The wet fractionating method might consequently be divided into the three main groups: solvent extraction, precipitation and enzymatic extraction.

Dry oat protein isolation method

Kaukovirta-Norja, *et al.* (2008) patented a method for fractionating oat. Oat protein was separated as a by-product fraction in oat beta glucan purification. Supercritical carbon dioxide system was employed to extract lipids. In some examples the carbon dioxide was used in combination with ethanol. Defatted oat

material passes milling, sieving and air separation steps. Fractionating allows to achieve protein content up to 78% in specific fractions. Unfortunately, the yield of protein concentrate remains unknown.

Lipids' removal could improve the fractioning process. Sibakov *et al.* (2011) reported the protein mass yield of 5% for dry fractionating. Yet the protein concentration could be as high as 73% when oats initial material is defatted. Researchers used supercritical CO₂ to remove oil from oats. The trials run at pilot scale although the amount (2310 kg) used for this trial demonstrated that the process might be scaled up.

Wet oat protein isolation methods

Wet fractioning method typically is divided into three main methods: solvent extraction, precipitation and enzymatic extraction, which were discussed below.

Yue *et al.* (2021) reported protein yields and structure extracted by choline chloride-dihydrate alcohol deep eutectic solvent (DES) and its water binary mixtures. Protein was extracted subjecting oat flour to DES in the ratio 1:9, which was then heated up to 80 °C for 60–120 minutes. Claimed method as being eco-friendly, due to its good biodegradability, low toxicity and being easy to apply in food, yielded in protein from 3.2 to 11.8% with the protein concentration of 38.9 to 55.8%. Protein recovery ranged from 13.9 to 41.4%. The optimal time of extraction was suggested to 90 min at the temperature of 80 °C.

The oat protein was isolated by Ma (1983) applying alkaline and salt extracts. Both extracts had higher than 90% concentration of protein. However, the yield of protein was much higher in alkaline extract than salt, counting 60% and 25%, respectively. Both isolates had close amino acid composition, slightly observed higher lysine and total essential amino acid content in alkaline isolate. For alkaline isolation, the pH was adjusted to 9.5 using diluted NaOH (0.015 N) at ratio 1:8, then centrifuged and supernatant was neutralized, recentrifuged and freeze-dried. Salt based oat protein isolate was obtained mixing diluting initial oat material with 0.5M CaCl₂ at a ratio 1:10, then centrifuged and dialyzed against cold water, precipitated, centrifuged and freeze-dried. This research was close to earlier studies by Cluskey *et al.* (1976) who revealed a method to produce oat protein concentrate by wet extraction. Researches used NaOH to maintain the slurry at pH 9 during extraction. Later Liu *et al.* (2009) isolated the oat protein by applying isoelectric precipitation to investigate oat protein composition and secondary structure. They applied alkaline extraction method close to what Ma (1983) reported. Oat flour was mixed with water, pH adjusted to 10.0 using 2 M NaOH. Filtered by mesh, the slurry was centrifuged at 3000 g. The supernatant had been centrifuged after pH was adjusted to 5.0 by 0.5 HCl

and kept for 15 min at room temperature. The resultant was washed 3 times, pH adjusted to 7.0 and freeze-dried. The oat protein concentration reached 87.0%. The amino acid balance was found similar to the initial oat material. Researchers reported an apparent increase of isoleucine, methionine, phenylalanine and arginine whereas asparagine, serine, glycine and cysteine were at lower content when compared to oat flour. The lysine and methionine content have not reached recommended by WHO/FAO/UNU (2007) values. Sodium dodecyl sulphate–polyacrylamide gel electrophoresis (SDS-PAGE) showed dominant two bands of protein with molecular weights (MW) of abt. 36 kDa and 22 kDa. These two agglomerates of peptides contributed to 80% of total protein. The secondary structure of oat protein isolate counted approximately 74%, 19% and 7% of β -sheet, α -helix and β -turn, respectively. Also, the ability of oat protein concentrate to self-assemble in aqueous solutions when concentration is higher than 0.5 mg mL⁻¹ was mentioned. That should increase the stability of protein in aqueous solutions by forming large aggregates (Liu *et al.*, 2009). Unfortunately, the yield of oat protein isolate was not reported.

A method of oat protein isolation applying enzymatic treatment was demonstrated by Prosekov *et al.* (2018). Defatted oat brans were treated by amyloglucosidase. It was supposed that the breakdown of cell wall polysaccharide membrane might led to protein releasing into suspension which later was separated. Suspended solids were washed forming fraction rich in protein, which concentration counted up to 83.8% (Dumas method). Although yield was not reported, the functional properties of the obtained protein were enhanced comparing to alkali extraction methods and discussed below. Another yet research demonstrated combined, enzymatic and alkaline method of oat protein extraction from oat brans (Jodayree, Smith, & Tsopmo, 2012). The oat protein was extracted applying different enzymes preparations, specifically with main enzymatic activities of xylanase, alpha amylase, amyloglucosidase, cellulase. Later slurries were treated with 2M NaOH to adjust pH to 9.5 and centrifuged. Supernatant was collected and precipitated. The highest protein concentration 82% (by modified Lowry method) was observed in the sample which had been treated with amyloglucosidase. Thereafter the obtained protein isolates were treated with endo-protease to enhance antioxidative properties.

Protein as a by-product

Oats are typically considered as a crop rich in healthy ingredients in particular non-starch polysaccharides extraction of those being a primarily technological process. Remaining protein rich fractions might be concentrated to high protein content

products. Vasanthan and Timelli (2008) invented the method of beta glucan extraction with the by-products recovery including protein, starch, fiber. Some side streams side remaining from ethanol extracted oat beta glucan and additionally treated by proteases could later be concentrated. Inglett (Patent No. US005082673A, 1992) patented process of hydrolyzing grain and starch with alpha amylase and recovering the soluble fraction. Recovered fraction contained the desired fraction of beta glucan, while the undesired fraction, insoluble residue, contained protein. Protein concentration depended on pH level which varied from 6 to 11. Concentration of protein in some examples reached up to 66%. Yield of protein in both references was not emphasized. Later Liu (2014) showed a modified wet fractioning method separating oats into beta glucan, protein, starch and other carbohydrates. The protein was extracted precipitating alkaline supernatant which was produced by providing milled groats, mixing it with water, centrifuging and extracting the residue in alkaline medium so that to obtain the supernatant. That resulted in protein concentration up to 92.62%. Beta glucan and starch were extracted in other streams with concentration of beta glucan and starch up to 44.84% and 81.69%, respectively. It was reported that defatting did not improve protein yield, although the increase in protein concentration was observed. Sibakov *et al.* (2011) fractioned defatted oats by air to obtain oat beta glucan, which resulted in mass yield of 7.8% of initial mass with a concentration of beta glucan 33.9%.

Functional properties of oat protein

The functional properties of oat protein such as thermal stability, solubility, emulsification, water hydration capacity and emulsification that are relevant to liquid food systems are being discussed below in the article.

Heat treatment is considered as a method which might modify protein functional properties. Marcone, Kakuda & Yada (1998) investigated oat globulin denaturation temperature. To specify the effect of heating the researchers determined thermal stability which relied on stabilizing structural factors (amino acid composition, compact packing/protein-protein contacts, intramolecular linkages and interactions). The oat globulin thermal transition occurred at 112 °C, the highest among all measured proteins.

Solubility of the protein is one of the most important factors when the protein functionality is discussed (Zayas, 1997). Kinsella (1976) described it as an obligatory determined method when studying a new or modified protein. Oat protein along with other cereal proteins typically has relatively low solubility. The solubility of oat protein highly depends on pH rate. Minimum solubility was observed at pH 5 and 6 for proteins extracted by alkaline and salt methods, respectively. Despite the similarity of oat

globulins to the 11S globulins of legumes, oat protein demonstrates lesser solubility in salt-based solutions (Brinegar & Peterson, 1982). Loponen *et al.* (2007) investigated solubility of oat globulins isolated from oat brans. The protein behavior was monitored under lactic acid fermentation conditions controlling pH and salt concentration. At pH from 7 to 8 protein dissolved or demonstrated acceptable solubility in solutions with 1 M NaCl and 0.5 M NaCl, respectively. At pH 5 and lower at those salt concentrations protein became insoluble. In contrast, non-salt and low salt concentration 0.05 M NaCl did not prevent to soluble the protein at acidic conditions. Solubility started to rise sharply at pH 4 and lower. Loponen *et al.* (2007) speculated that acidic conditions which present during lactic acid fermentation could induce protein unfolding. That might cause the formation of globulin aggregates which consequently reduced protein solubility in salt-buffer. Contrasted explanation of protein solubility in low or non-salt solution was not presented. Prosekov *et al.* (2018) reported high solubility for oat protein extracted enzymatically by amyloglucosidase. Unexpectedly, the optimal solubility of oat protein was achieved at pH 5–6. Nitrogen solubility index equaled approximately to 50%. The achieved solubility was about 4 times higher than comparing to protein extracted by NaOH. Another yet embodiment of increasing protein solubility was reported by Guan *et al.* (2007). Oat protein derived from oat brans was prepared by alkali extraction and then treated by trypsin. The solubility of trypsin treated oat protein at pH 5 reached up to 68.2%, while non-treated protein solubility was 7.3% only. The increase in solubility was observed when protein was treated in more alkali or acid medium. Guan *et al.* (2007) supposed the increased solubility might be related to structure demolishing, molecular size decreasing and exposing more charged and polar groups to surrounding water. Jiang *et al.* (2015) nearly doubled oat protein solubility after oat protein enzymatic deamidation. Oat protein fractions obtained through air separation were treated by food grade protein-glutaminase. Runyon *et al.* (2015) investigated oat protein solubility dependence on temperature treatment. Oats treated by steam at 102 °C for 50 min and then dried at 110–120 °C for 50 min reduced in availability of soluble protein up to 50%. Albumins and prolamins were affected at higher extent that comparing to globulin fraction. Solubility test assumed oat protein extraction from oat flour in 200 mM sodium phosphate buffer at pH 9.5 which contained protease inhibitor. Mirmoghtadaie, Kadivar & Shahedi (2009) demonstrated the effect of succinylation and deamidation on functional oat protein isolate properties. Oat protein was isolated from oat flour which was diluted in NaOH solvent by precipitating, neutralizing and freeze drying.

Deamidation and succinylation increased oat protein solubility index, from 22.9% to 24.2% and 86.8% respectively. Authors stated such a dramatic solubility increase of succinylated protein was caused by increased its net negative charge and increased protein-water interactions. Yue *et al.* reported (2021) decreasing in solubility of oat protein which was prior subjected to DES. It was speculated that higher amount of β -sheet and β -turn in oat protein extracted by the mentioned method 'may counteract the positive contribution of hydrophilic amino acids residues on oat protein solubility'. However, oat protein solubility increased when oat protein was extracted by 1,4-butanediol based DES/water binary mixture. On the other hand, the declination of solubility was reported when 2,3- butanediol based DES/water binary mixture was applied for extraction.

The emulsification of protein might be dependent on protein secondary structure and protein ability to self-assembly forming the protein adsorption layer at the water-air interface (Liu *et al.*, 2009). The emulsification properties of oat protein isolate extracted in alkaline medium demonstrated close values to soy isolate, whereas the oats' isolate extracted in salt medium emulsification properties were less effective. Ma (1983) determined emulsification properties of oat isolate at different pH. The weakest emulsification activity was observed between pH 4–6. Bell shaped curves resembled the protein solubility curves where the minimum solubility of protein was determined at the identical pH. Surface hydrophobicity influences the functionality of protein greatly, particularly in emulsification (Nishinari, 2014; Chen *et al.*, 2016). We could speculate relying on the similarity of oat globulins to soy globulins, that the large protein molecular mass and inherent hydrophobic interactions between nonpolar groups might oat protein turn into a proper emulsifier if modified adequately. Ma (1983) determined the surface and exposed hydrophobicities for oat protein isolate. The expressed values of surface hydrophobicity for alkaline isolate ranged from 240 to 269, depending on oat variety. In comparison, soy protein isolate and wheat gluten showed 95 and 75, respectively. Enzymatically treated by protease, oat protein demonstrated improved emulsifying activity; meanwhile, the emulsifying stability has been reported as being poorer comparing to untreated or temperature treated oat protein. It was suggested the shorter and less globular protein layers formed less stable protein layers around the oil droplets (Guan *et al.*, 2007).

Deamidation and succinylation increased emulsion activity of oat protein isolate (Mirmoghtadaie, Kadivar, & Shahedi, 2009). Authors assumed that deamidation led to increase in solubility and surface hydrophobicity, yet increase in solubility and exposure of buried functional groups of protein were attributed

to succinylaton. Emulsion activity was increased from 49.0 $\text{m}^2 \text{g}^{-1}$ to native oat protein to 98.3 $\text{m}^2 \text{g}^{-1}$ and 189 $\text{m}^2 \text{g}^{-1}$ after altering it by deamidation and succinylation, respectively. On the other hand, emulsion stability index for deamidated protein was slightly lower than native protein, yet succinylated protein decreased to 1692 s from 3756 s in terms of emulsion stability.

Water hydration capacity determined using of oat protein isolate was considerably lower than comparing to soy isolate, 0.8 mL g^{-1} to 2.5 mL g^{-1} . It was close to wheat gluten capacity which was in the range of 1.0 mL g^{-1} (Yung Ma, 1983). Later functionality test was presented by Ma (1983) for oat concentrates. The hydration capacity for oat concentrates prepared by alkali extraction increased significantly comparing to oat isolates. The water hydration capacity was up to 2.70 mL g^{-1} . Defatted by hexane oat protein concentrates showed lower hydration capacity. Interestingly, the dried supernatant rich in carbohydrates (59.6%) also demonstrated significantly higher water holding capacity, 3.0 mL g^{-1} . Based on this data we could speculate that the water holding capacity of the oats protein heavily depends on the level of carbohydrates which are present in the analyzed sample. Another yet research (Prosekov *et al.*, 2018) found the water holding capacity for protein extracted by enzymatic method 3.73 mL g^{-1} . Protein was extracted from oat brans. The values announced are higher than compared to alkali extraction method.

Good foamability of oat protein isolate which was equal or in some cases higher than wheat gluten or soy protein isolate (Yung Ma, 1983) was revealed. In addition, oat protein foaming ability increased when treated by protease. However, the foaming stability demonstrated the opposite relationship (Guan *et al.*, 2007). Foaming properties were also investigated by Prosekov *et al.* (2018) who determined the foaming ability and foam stability for enzymatically extracted oat protein. Researchers noticed increase in foaming ability while the foam stability decreased. Slight increase in foaming capacity was also observed after deamidation (Mirmoghtadaie, Kadivar, & Shahedi, 2009). Moreover, the facilitation in formatting of elastic layer due to the small molecular size of deamidated protein was observed. The decreased foaming stability was in line with other observations investigating protein size reduction as excessive increase in charge prevents formation of elastic film at the air-liquid point due to reduced protein-protein interactions.

Limitations

The methods related to wet extraction do not disclose the altering properties or chemical changes of protein products. The harsh alkali or acid treatment usually leads to chemical changes in protein. Main of those were comprehensively presented by Cartus (2017). Two general chemical changes are usually

observed – the formation of cross-linked amino acids, like lysinoalanine, lanthionine or histidinoalanine and racemization (epimerization) of L-amino acids into D-isomers. For instance, the formation of lysinoalanine begins at pH 9, reaches maximum at 12.5 (Friedman, Levin, & Noma, 1984). Temperature might also affect the formation of lysinoalanine; wheat gluten is affected even at pH 5, then temperature reaches 100 °C (4h) (Sternberg & Kim, 1977). These chemical changes affecting proteins are highly undesired, as those significantly decrease product quality and nutritional value. Many of studies mentioned that wet protein purification performed treating protein at critical conditions which might induce the formation of mentioned undesired chemical changes to some extent.

Commercial Oat protein

Despite the positive functional properties and relatively high nutritional value the oat protein in its concentrated form is not widely available. Some attempts to commercialize concentrated protein were typically raised in Scandinavian countries. Oat protein produced by Lattmanen (PrOatein Oat Protein | Lantmannen Oats, n.d.) seems to be the only currently commercialized protein concentrate in the market. The product contains more than 50% of protein and is rich in oil and maltodextrins, counting about 16–19% and 20–24% respectively. Company employs patented technology by which the oat protein concentrate is extracted from oat brans. The process comprises wet milling process during which oat material is mixed with aqueous liquid and treated with alpha amylase. The suspension is then decanted to remove insoluble fiber. Along with protein other oat derivatives, like oat beta glucan or oat dextrin might be obtained during the process. Company states the product is suitable for various applications including bakery, beverages, meat substitutes, etc. The oat product properties highly differ from traditional plant-based proteins such as soy or pea (*Pisum sativum*) in terms of oil content, structure and functional properties.

There were some attempts to establish production units in the USA, like Oat Tech, Inc. Company along with protein products similar to Latmannen product, concentrated some streams of oat dextrins. Company's product Oat Protein 55 produced by

patented technology (Whalen, 2016) concentration was about 55%. These attempts were not sustainable and the information available is very limited to discuss the issues which terminated Oatech's activity.

Some recent research in dry fractionating allows also to achieve high purity of protein wherein the concentration of protein could reach up to 73%. Fazer company recently announced that it had obtained a license to VTT Research Centre of Finland (Fazer, 2015). Dry fractionating allows to retain protein in form providing its natural state although protein is yet not commercially available though not studied in the article. The protein fractions obtained through typical or slightly modified dry fractionation methods are not included in the study due to their low protein concentration and limited applicability in aqueous food systems.

Conclusions

Oat protein is a valuable source of protein. Amino acid composition of oat storage protein globulin is close to soy's glycinin with little imbalance.

Published oat protein extraction methods highly rely on wet extraction technique, in particular using precipitation method, which in some cases enables achieving of highly purified protein up to 90% of purity. However, such a method rises concerns about extracted protein further applicability in food as limitation such as formation of cross-linked amino acids might decrease protein value. Enzymatic protein extraction might be a future trend in oat protein extraction technique.

Relatively large oat protein molecular mass and inherent hydrophobic interaction between nonpolar groups might be positive preconditions for oat protein acting as a proper emulsifier. Water hydration capacity of oat protein is lower than compared to soy protein. Oat protein foaming ability is in range or in some cases higher than comparing to soy or wheat protein isolates. Protein modification in particular size reduction increases foamability properties while the foam stability decreases after such a modification.

Few technologies are currently commercially established. However, the increased demand on plant-based protein might stimulate development of oat protein isolation and modification technologies.

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EVALUATION OF PHYSICAL AND CHEMICAL COMPOSITION OF CONCENTRATED FERMENTED CABBAGE JUICE

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Abstract

Fermented products have gained worldwide popularity for their nutritional and health aspects. Many studies have been done on this topic, including fermented cabbage (sauerkraut). Yet little or no studies are done on evaluation of fermented cabbage juice which is considered as by-product of sauerkraut production, still rich in bioactive compounds. In order to reduce food waste, sustainable solutions are being searched for to preserve valuable fermented cabbage juice. The aim of this study was to evaluate chemical and physical composition of concentrated fermented cabbage juice and their changes after storage. The fermented cabbage juice was concentrated on falling film evaporator from 9.2 till 34.3 °Brix. Physio-chemical (moisture, pH, total soluble solids, total phenol content, antiradical activity by DPPH and ABTS⁺, ascorbic acid, total sugar profile, nitrates and minerals) and microbiological (lactic acid bacteria, total plate count) analyses were carried out. Concentrated fermented cabbage juice is a source of minerals and phenol compounds as well as salt substitute in food applications. After 6 months of storage there is significant degradation of ascorbic acid but total phenol content is not affected. The evaporation process did not inhibit microbiological activity; as a result, there is a decrease in lactic acid bacteria but increase in total plate count.

Key words: fermented cabbage juice, concentrate, evaporation, storage, nutritional value.

Introduction

Fermented cabbage juice is considered as by-product, yet it is rich in bioactive compounds. There are many studies on fermented cabbage (sauerkraut); however, there are no studies on composition of fermented cabbage juice. Fermented cabbage is rich in vitamin C (14.7 – 75 mg 100 g⁻¹), biogenic amines, organic acids, (Satora *et al.*, 2021a), especially lactic acid, sugars like glyucose and fructose, phenolic compounds and glucosinolates, as well as minerals like Na (661 mg 100 g⁻¹), Ca (30 mg 100 g⁻¹), K (170 mg 100 g⁻¹) (Peñas *et al.*, 2017). Sauerkraut juice contains all the same bioactive compounds. Fermentation process increases vegetable shelf life, nutritional value, sensory quality with unique flavours and textures as well as fermented vegetables promote health of gut microbiome and digestive system, enhancing the immune system (Xiang *et al.*, 2019).

Investigation of the potential use of this valuable product can bring innovative and sustainable solutions in the production process (Beganović *et al.*, 2014).

Generally, juices are concentrated in order to reduce transport, storage and packaging costs (Dincer *et al.*, 2016) as well as prolong shelf life by reducing water activity (Brugnoni *et al.*, 2013). Fruits and vegetables are usually consumed fresh in season, but not all the crop can be utilized that way (Sabanci & Icier, 2017) so different production techniques are being used – dried, frozen, canned and concentrated. Orange, apple and fruit juice mixtures are the most frequent juices concentrated worldwide (Adnan *et al.*, 2018).

One of the techniques applied in concentrating juice is via evaporation – separating water from juice by means of heat energy and pressure. There is a variety of evaporation techniques used – multifactor,

kettle, vacuum pan evaporators, as well as rising and falling film evaporators (Adnan *et al.*, 2018). Falling film evaporator was used in our study as it is suitable for heat-sensitive products and has a short residence time and high heat transfer coefficients (Chawankul *et al.*, 2001). The principles of falling film evaporator: the juice or liquid to be concentrated is distributed at the top of heating tubes letting flow down the inside of the tube walls as a thin film. The liquid is partially evaporated due to external heating of the heating tubes. The downward flow, caused initially by gravity, is enhanced by the parallel, downward flow of the vapor formed (Gong *et al.*, 2020).

The more juice is concentrated, the less it resembles original product, even if reconstituted back to original dilution (Adnan *et al.*, 2018) this can be due to vulnerability of volatile, flavouring and sugar compounds on heat processing conditions. However, concentrated juices have higher resistance to microbial (Dutra *et al.*, 2021) activity (Sabanci & Icier, 2017) and can preserve antioxidant capacity and bioactive compounds as in concentrated grape juice (Deniz Korkmaz, n.d.). Concentrated fermented cabbage juice could be used in food industry like meat, bread, etc. production. Shelf life of concentrated juices vary depending on raw materials and are from one year to three years (Salehi, 2020). The aim of this study was to evaluate chemical and physical properties of concentrated fermented cabbage juice and their changes after storage.

Materials and Methods

Cabbages of harvest of the 2019 were used for this experiment. Fermented cabbages were obtained using traditional technology applied in LTD Dimdini. Average ratio of cabbages and juice was 3:1. Initial

soluble solids content of fermented cabbage juice were 9.1 °Brix. Fermented cabbage juice was concentrated using falling film evaporator FF2000 Pilot with the temperatures in calandria being 68 °C and in separator 62 °C, capacity 1460 kg h⁻¹ located at production plant of 'Smiltenes piens' Ltd. The juice was evaporated till 34.3 °Brix which was the maximal evaporation ratio in first stage evaporation. Pilot experiments of concentration were performed on laboratory scale rotary evaporation equipment (Heidolph Laborata 4000 efficient) reaching 30 °Brix, to evaluate stability of compounds. After evaporation process the obtained concentrate was cooled down and filled in 10 L plastic bags, stored in refrigerator at 4 ± 2 °C. Totally 2000 L of concentrate were obtained, for current experiment 30 L were used and the rest of it was used for new product development. Three replications were carried out throughout the experiment.

Analytical procedures were carried out in Latvia University of Life Sciences and Technologies, Faculty of Food Technology and in collaboration with laboratory group J.S. Hamilton. Physical, chemical and microbiological parameters were tested in two periods of time – right after the evaporation process and after 6 months of storage in the refrigerator.

Physico-chemical parameters

pH was measured with pH-meter Jenway 3510 (Baroworld Scientific Ltd., UK) applying standard method LVS ISO 5542:2010. Soluble solids content (°Brix) was measured using digital refractometer Refracto 30GS (Mettler Toledo, Japan) as described in standard method ISO 2173:2003. For moisture content samples were dried at 105 ± 1 °C (Universal Oven UF55, Memmert, Germany) till constant weight, according to standard ISO 6496:1999. Salt content was determined by titration as described in Mohr's method, according to standard IDF 12/ISO 1738:2004. Silver nitrate solution and potassium chromate indicator were used (Deniz Korkmaz, n.d.).

Nutritional composition

Protein (N*6.25) amount was determined according to method PB-116 ed. II of 30.06.2014. Dietary fiber was determined according to AOAC 991.43:1994. Ash content was determined according to PN-A-75101-08:1990+Az 1:2002. Minerals were determined according to method PB-223/ICP, ED II of 12.01.2015. Fat content was determined according to PB-286 ed. I of 26.09.2014. For sugar profile enzymatic – spectrophotometric method was used. Carbohydrates were calculated as dietary fibre and total sugar content. Energy value was determined according to Regulation (EU) No 1169/2011 of the European Parliament and of the Council of 25 October 2011. Nitrates were determined according to method PN-A-75112:1992. Analytical procedures were done by laboratory group J.S. Hamilton.

Bioactive compounds and antioxidant activity

For total phenol content and antiradical activity, extracts of 10 mL of the sample and 20 mL ethanol (80:20 v/v) were made and stirred for 2 hrs, then filtered. The total phenol content was determined by Folin – Ciocalteu method as described by Singleton et al. (Singleton *et al.*, 1999) with some modifications, as described previously (Jansone & Kampuse, 2019) Absorption was read at 765 nm on a spectrophotometer Jenway 6300 (Baroworld Scientific Ltd., UK). For antiradical scavenging activity by DPPH, 3,5 mL freshly made DPPH stock solution (0.004 g of 2,2-diphenyl-1-picrylhydrazyl was mixed with 96% ethanol to reach the absorption of 1.000 ± 0.02 at 517 nm) were added to 0.5 mL sample extract and left to react in the dark place for 30 min, as described by K. Thaipong (Thaipong *et al.*, 2006). The analyses were done in three replications and the results were determined spectrophotometrically. For antiradical decoloration method by ABTS⁺, stock solution was made with 2,2-azinobis-(3-ethylbenzotiazoline-6-sulphonic acid), phosphate buffered saline and potassium per sulphate as the oxidant and left to react for 16 h in the dark (to reach the absorption of 0.800 ± 0.030 at 734 nm). 5 mL of stock were added to 0.05 mL sample extracts, left to react for 10 min. The analyses were done in three replications and the results were determined spectrophotometrically, as described by S. Rokayya (Rokayya *et al.*, 2013) with some modifications. Ascorbic acid content was determined by titration after iodine method T-138-15-01:2002 which defines L-ascorbic acid that is reduced form of ascorbic acid, described by D.Segliņa (Segliņa, 2007).

Microbiological parameters

Microbiological parameters – 10 mL of the fermented cabbage juice concentrate were diluted in 90 mL sterile saline (0.9% NaCl) in an internal filter bag and mixed in a stomacher (Bagmixer Interscience, Bois Arpents F.) for 1 min. A 1 mL and 0.1 mL of filtrate were cultured on MRS agar (Scharlau, ref. nr. 01-135-500) for lactic acid bacteria, according to standard LVS ISO 15214:1998 and on PCA (Plate Count Agar) agar (Scharlau, ref.nr. 01-161-500) for total plate count, according to standard LVS EN ISO 4833-1:2013. The samples were incubated as follows: MRS 37 °C 72 h and PCA 30 °C 48 h. Enumeration was carried out on Acolyte colony counter.

Statistical data analyses

T-test, arithmetic mean and standard deviation was used on programme Excel (Microsoft) to determine statistical differences.

Results and Discussions

Chemical composition of the cabbage, sequentially fermented cabbage and its products, like dehydrated or concentrated fermented cabbage juice, are strongly

influenced by many factors – meteorological and soil conditions (Satora *et al.*, 2021b), storage and temperature, production process (Yang *et al.*, 2020) variety and other effects (Burdurlu *et al.*, 2006).

Nutritional value of concentrated fermented cabbage juice is summarized in Table 1.

Table 1
Nutritional value of concentrated fermented cabbage juice

Parameters	Unit	Content per 100 g
Energy value	kJ	320
Carbohydrates	g	13.0
- including sugars	g	7.5
Glucose	g	5.5
Fructose	g	1.5
Maltose	g	0.2
Galactose	g	0.3
- dietary fibre	g	1.1
Protein	g	5.3
Fat	g	<0.1
Ash	g	9.42
Salt	g	6.33

Energy value of concentrated fermented cabbage juice was 320 kJ 100 g⁻¹. Carbohydrates including sugars and dietary fibre was 13 g 100 g⁻¹, protein was 5.3 g 100 g⁻¹. Salt content in fermented cabbage juice was 6.33 g 100 g⁻¹. According to EU regulations ((EC) No 1924/2006), it is considered as high and thus can be used in food formulations substituting salt.

The sugar content in concentrated fermented cabbage juice was 7.5 g, with glucose being 5.5 g as dominated monosaccharide. As it is mentioned by other authors, the concentration of total sugars in sauerkraut samples varies from 0.3 to 1.7% wet weight, glucose being < 1 (Hughes & Lindsay, 1985). The sugar (glucose, fructose, sucrose) content varies in fermented cabbage and its juice due to metabolic and microbiological activity (Xiong *et al.*, 2016).

The ash content in concentrated fermented cabbage juice is 9.42 g, thus it contains a variety of minerals like Mg, Cu, K Ca, Fe as shown in Table 2. In comparison, fresh cabbage contains 200 – 300 mg 100 g⁻¹ and fermented cabbage - 700 – 800 mg 100 g⁻¹ minerals (Khanna, 2018). The fermentation process may increase the mineral content of the cabbage (Ifesan *et al.*, 2014). The role of minerals in human nutrition and metabolism is essential (Mensink *et al.*, 2013), but amount of potassium in this concentrate is noticeable. It is the main cation in intracellular fluid and ensures cell function (Healthcare Research, n.d.). Potassium interacts in regulating blood pressure,

reduction of kidney stones and cardiovascular diseases (Hmelak, Gorenjak, & Cencič, 2013; Sākumlapa Slimību Profilakses un Kontroles Centrs, n.d.)

Brassicaceae (rocket, mustard as well as cabbage) vegetables are considered as nitrate accumulating sources like many green leafy vegetables, and there is a large variation in concentration what is influenced by many factors. The nitrate concentration in leafy vegetables is regulated by European Commission (Commission, 2010)) and the nitrate content is considered as very low if it is below 200 mg 100 g⁻¹ fresh weight (Hmelak, Gorenjak, & Cencič, 2013; Sākumlapa | Slimību Profilakses un Kontroles Centrs, n.d.). The nitrate content in concentrated fermented cabbage juice is considered as low with no harmful impact on health, according to WHO (World Health Organisation).

Table 2
Mineral and nitrate content in concentrated fermented cabbage juice and acceptable daily intake

Parameter	Results	RDI*
Minerals	mg 100 g ⁻¹	mg/day
Magnesium	67.8	280
Copper	0.11	0.9
Potassium	1358	3100
Calcium	238	800
Iron	1.14	15
Nitrates		
Nitrates as NaNO ₃	151	222
Nitrates as NO ₃ ⁻	110	222

* Recommended daily intake. These recommendations are for female 18 – 60 years old. The RDI for nitrates is for grown-up, 60 kg body weight (Piljac-Žegarac *et al.*, 2009; Slimību Profilakses un Kontroles Centrs, n.d.)

Physicochemical and microbiological parameters are summarized in Table 3.

- values marked with different letters in the same row differ significantly at the level of significance p<0.005.

pH of the concentrated fermented cabbage juice was from 3.92 ± 0.06 at the beginning of this experiment to 3.86 ± 0.04 after 6 months. The initial pH of fermented cabbage juice usually is 3.4 – 3.8. Total soluble solids of concentrated fermented cabbage juice was 34.33 ± 0.02 °Brix, after 6 months of storage the soluble solids slightly increased to 34.74 ± 0.02 °Brix which could be explained by vague evaporation. Due to our previous experiments, not described in this article, total soluble solids of 34 – 35 °Brix was optimum for first stage evaporation.

Table 3

Physicochemical and microbiological parameters of concentrated fermented cabbage juice before and after storage

Parameters	Concentrated juice	
	Before storage	After storage
pH	3.92 ± 0.06a*	3.86 ± 0.04b
Soluble solids, °Brix	34.33 ± 0.02b	34.74 ± 0.02a
Moisture, %	70.29 ± 0.19a	69.44 ± 0.11b
Total phenols, mg GAE 100 g ⁻¹	530.06 ± 12.72a	521.19 ± 10.29a
DPPH, mg TE 100 g ⁻¹	822.17 ± 12.02a	350.23 ± 5.24b
ABTS, mg TE 100 g ⁻¹	23.70 ± 1.74a	20.40 ± 3.23b
Ascorbic acid, mg 100 g ⁻¹	110.00 ± 4.34a	26.66 ± 2.47b
Lactic acid bacteria, CFU g ⁻¹	4.6 x 10 ⁴ a	1.2 x 10 ⁴ b
Total plate count, CFU g ⁻¹	3.8 x 10 ⁴ a	1.6 x 10 ⁵ b

Ascorbic acid content. There was considerable decrease in ascorbic acid content in the concentrate during storage from 110 to 26.6 mg 100 g⁻¹, and as it can be seen from our experiment, even storage at 4 ± 2 °C temperature is not sufficient for stabilization of ascorbic acid degradation. As it is mentioned by other authors, ascorbic acid (AA) degradation (usually anaerobic during storage) is influenced by many storage factors like storage time, light and others (Piljac-Žegarac *et al.*, 2009).

Total phenol content (TPC) in concentrated fermented cabbage juice was 530.06 ± 12.72 and 521.19 ± 10.29 mg GAE 100 g⁻¹ after 6 months of storage. Like the stability of AA is influenced by many factors, so is the stability of dark fruit juice polyphenols (Dianawati *et al.*, 2016). The scientists also studied the fluctuations in the total phenol content during storage in the dark fruit juice concentrates. There is a decrease of TPC observed from 2 weeks to 6 months of storage at ± 4 °C after which, however total phenol content increases again. The storage time and fluctuations of the TPC are individual for different fruit or berry juices. “It is possible that during juice storage, some compounds are formed that react with the Folin–Ciocalteu reagent and significantly enhance the phenolic content” (Yang *et al.*, 2020). There are several findings that suggest that phenolic compounds remain stable and do not lower the concentration during storage (Yang *et al.*, 2020).

Antiradical activity by DPPH was 822.2 ± 12.02 after evaporation process, and it dropped to 350.2 ± 5.24 mg TE 100 g⁻¹ after storage. There were fluctuations observed during storage in antiradical activity by DPPH in oranges (Arena *et al.*, 2001). The antiradical activity in black mulberry juice concentrate also decreased during storage and was influenced

by many factors, like storage time, temperature and composition of the product (Dincer *et al.*, 2016). The loss of ascorbic acid may have a contribution to decrease of antiradical activity (Yang *et al.*, 2020). Antiradical activity by ABTS results were 23.7 ± 1.74 at the beginning of the experiment and 20.40 ± 3.23 mg TE 100 g⁻¹ after storage.

Microbiological Parameters

The viability of microorganisms is influenced by many factors (Yang *et al.*, 2020) as well as their activity. Fermented cabbage and its juice are considered a valuable source of lactic acid bacteria (LAB) (Yang *et al.*, 2020), so in our study we were paying closer look at LAB survival during concentration process and storage impact. The LAB count after evaporation process was 4.6 x 10⁴ CFU g⁻¹ but it decreased after 6 months of storage and was 1.2 x 10⁴ CFU g⁻¹. Total plate count, acted quite the opposite being 3.8 x 10⁴ CFU g⁻¹ after evaporation and 1.6 x 10⁵ CFU g⁻¹ after storage period.

Conclusions

Concentrated cabbage juice with soluble solids content 30 °Brix contained carbohydrates as the main nutrient, followed by high ash content, including various minerals most abundant being potassium 1174 mg 100 mL⁻¹. The nitrate content in concentrated fermented cabbage juice is recognized as low (<200 mg 100 g⁻¹). After the storage of concentrated fermented cabbage juice for six months at 4 °C temperature, total phenol content decreased from 530.06 to 521.19 mg GAE 100 g⁻¹, whereas antiradical activity (by DPPH) and ascorbic acid content decreased significantly from 822.17 to 350.23 mg TE 100 g⁻¹ and 110.0 to 26.66 mg 100 g⁻¹ accordingly. LAB count decreased during storage from 4.6 x 10⁴ CFU g⁻¹ to 1.2 x 10⁴ CFU g⁻¹ whereas total microorganism activity increased

3.8×10^4 CFU g^{-1} to 1.6×10^5 CFU g^{-1} . Concentrated fermented cabbage juice is a source of minerals and polyphenol compounds as well as due to a high salt content (6.33%) could be applied as salt substitute in food applications.

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RESEARCH ON GERMINATED WHEAT GRAIN, BROCCOLI, ALFALFA, RADISH AND HEMP SEEDS MICROBIOLOGICAL SAFETY

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Abstract

For a long time, germinated seeds have been used in food as a healthy product with high nutritional value and as a decor for exquisite dishes today. However, there have been many foodborne outbreaks in Europe, the United States, and other parts of the world associated with pathogens contamination of sprouts. These outbreaks pose a constant challenge to the entire sprouts industry. The aim of this study was to determine the presence of Shiga toxin-producing *Escherichia coli* (STEC), *Salmonella spp.*, and potentially pathogenic bacteria in germinated grains and seeds intended for industrial food production and ready for use without further processing. In this study, grains of wheat (*Triticum aestivum*), seeds of broccoli (*Brassica oleracea*), alfalfa (*Medicago sativa*), radish (*Raphanus sativus*) and hemp (*Cannabis sativa*) were germinated for 72 hours and were evaluated compared with ungerminated grains and seeds. The presence of *E. coli* was assessed by the inoculation of enrichment broth to Tryptone Bile X-glucuronide (TBX) and Eosin methylene blue (EMB) agars, and colony characterization with MALDI-TOF. *E. coli* was carried out in accordance with LVS ISO 16649-2:2007. The presence of STEC was determined in accordance with ISO/TS 13136:2012. *Salmonella spp.* detection was in accordance with ISO 6579-1:2017. As a result, *E. coli*, *Salmonella spp.*, and STEC were not found in any sample. However, environmental bacteria were detected in TBX dry seeds and 12 h – soaked seeds. The presence of *Enterobacteriaceae* was found in all samples by colony characterization on EMB by MALDI-TOF. The results show that the sprouts and edible seeds available in Latvia could be included as healthy and relatively safe food.

Key words: grains, germination, seeds, pathogenic bacteria.

Introduction

Today, consumers are particularly aware of the health problems associated with food additives. Foods “natural”, “eco”, “bio”, processed without chemicals and preservatives are becoming more and more attractive. Sprouts have also been considered healthy food for more than 5,000 years; they are rich in nutrients, low in calories, visually alluring, and their simple production process is environmentally friendly – the qualities that are appealing to today's food consumers (Choe, Yu, & Wang, 2018). However, warm and humid germination conditions are ideal for the growth of microorganisms (Bergspica *et al.*, 2020). This raises food safety concerns not only about food production methods but also about how food is processed, stored, sold and consumed (Anal *et al.*, 2020). Despite its healthy image, sprouts are one of the foods associated with foodborne outbreaks. Between 1990 and 2002, about 10% of outbreaks in the United States were related to sprouted seeds. Several outbreaks of *Salmonella spp.* and *Escherichia coli* O157:H7 and O157:NM infections were observed each year. In Japan, 9451 cases of illness and 12 deaths (all children) were reported in 1996, and this attracted worldwide attention (Sikin, Zoelner, & Rizvi, 2013). One of the main pathogens involved in germ-related outbreaks is Shiga toxin - producing *E. coli* (STEC). An outbreak of STEC infection in May 2011, mainly in Germany and Central Europe, claimed the lives of 54 people and was associated with fenugreek sprouts infected with an unusual *E. coli* strain O14:H4 with increased virulence and antibiotic resistance (EFSA,

2011b). To ensure the protection of public health, in 2013, the Commission established the microbiological STEC criterion for sprouts in Regulation (EU) No 209/2013. COMMISSION REGULATION (EC) No 2073/2005 of 15 November 2005 on microbiological criteria for foodstuffs (Official Journal of the European Union, 2005, L 338), which lays down the common food safety and process hygiene criteria for food in EU countries and applies to sprouts. According to it, STEC belongs to serogroups O157, O26, O111, O103, O145 and O104:H4 sprouts must not contain 25 g (EC) No 2073/2005). The reference analytical method is CEN/ISO TS 13136, the main step of which is based on the determination of the Shiga toxin coding genes *stx1* and *stx2* (EU) No 209/2013. STEC molecular diagnostic tests that the manufacturer must take to comply with the regulation and demonstrate that the manufactured product is safe for the consumer, may pay dearly. With the entry into force of the Regulation (EU) No 209/2013. Latvian sprouts producers were not able to meet all the requirements; therefore, a product manufactured in Latvia is currently not available on the Latvian market. The prevention of seed contamination is particularly important, in particular the long-term survival of pathogenic bacteria on the seed and its multiplication during the production of germinated seeds. In sprouts, contamination with microorganisms can come from the environment. One of the most important risk factors is related to the impact of agricultural practices on seed production and storage: contaminated irrigation water, manure, the presence of animals and rodents, dirty harvesting

equipment and transport containers, and the seedling production process. There are various methods of physical and chemical treatment (rinsing or soaking in various chemical solutions or in hot water, dry heating, irradiation, hydrostatic pressure, UV light, etc.), but none of them has so far been able to provide pathogen-free seeds (EFSA, 2011). One of the physical methods used in the study is rinsing the seeds with drinking water at 12 hour intervals, and the rinsing water is visually clean.

The aim of this study was to determine the presence of Shiga toxin-producing *Escherichia coli* (STEC), *Salmonella* spp., and potentially pathogenic bacteria in germinated grains and seeds intended for industrial food production and ready for use without further processing.

Materials and Methods

Plant materials. The seeds were purchased in the local market. Broccoli (*Brassica oleracea*) expiration date November 2021, Lot: 62/14 and radish (*Raphanus sativus*) seeds expiration date July 2021, Lot: 275/A, originated in Italy in 2019, hemp (*Cannabis sativa*), wheat (*Triticum aestivum*) and alfalfa seeds were harvested in Latvia in 2019 and 2020. Seed preparation and germination were performed in the laboratory of the Faculty of Food Technology, Latvia University of Life Sciences and Technologies. Samples were packed in sterile bags and placed in a cooler bag and stored at 4 ± 3 °C until delivered to the Institute of Food Safety, Animal Health and Environment "BIOR". Microbiological analyses were carried out at the Institute of Food Safety, Animal Health and Environment "BIOR".

Samples germination

The study was conducted in two parts. The first part was analyzed in February 2020 and the second part in November 2020. Dry grains, seeds and sprouts from each part containing 8 samples (wheat grains, seeds of broccoli, alfalfa, radish and hemp), each weighing 10 g and 25 g used for microbiological analysis, in triplicate. The second part also focused on the microbiological contamination of the product with production packaging and storage. The grains and seeds were soaked for 12 h and then were sprouted for 3 days (72 h), but before that, they were washed in drinking water until the water used was visually clear. Clean grains and seeds were soaked in drinking water in a ratio of 2:1 (water:seed). The soaking was done in a polystyrene (PS) bowl for 12 h in the dark at 22 ± 2 °C. After 12 h, the seeds and grains were rinsed in drinking water until the rinsing water was visually clear. Rinsing is the main physical treatment process that separates dirt and microorganisms from seeds. Samples rinsing was performed every 12 h for 3 days. The rinsed seeds and grains were germinated in a glass

container in room at 22 ± 2 °C, where daylight winds overnight. A day length is 8 h and a daylight average is 60 ± 5 lx. Darkness lasts 16 h at 0 lx. Germinated hemp sprouts were not used in further studies because they did not show good properties – they are visually fresh, crunchy with a good taste according to hemp but when eating the sprouts, the bark is hard and difficult to chew.

Samples storage

After 3 days of germination, the sprouts were rinsed with drinking water until the water was visually clean and packaged in closed polypropylene 300 ml containers. Wheat sprouts 100 g, alfalfa sprouts 50 g, broccoli and radish sprouts 75 g were packaged. Packaged sprouts were stored for 8 days in a cold chamber at 3 ± 2 °C in the dark, from which 10 g and 25 g were taken for microbiological analysis.

Microbiological analyses

Microbiological analyses were performed for all dried seeds and wheat grains, soaked and sprouted wheat grains, broccoli, radish and alfalfa seeds, the test was also carried out after sprouting and after 5 and 8 days of storage. From each sample 25 g STEC and *Salmonella* spp. and 10 g *E.coli* and *Enerobacteriaceae* spp were taken.

Enerobacteriaceae spp. determination with Violet red bile glucose

Sample of *Enerobacteriaceae* spp the decimal dilutions preparation has been performed in accordance with the standard LVS EN ISO 6887-1. Dry grains and seeds were tested as controls. Each sample portion was performed in triplicate. 10 ± 0.02 g of the sample per replicate was weighed in sterile filter bags and 90 ml of MRD (maximum recovery diluent) was added. The sample was processed in a Stomacher® blender at 230 rpm for 30 s. 1 ml of the sample and 1 ml of the $10 \times$ MRD diluted sample into a sterile Petri dish was brought. 15 ml of VRBG (Violet red bile glucose) medium, mix thoroughly was added and the medium was allowed to solidify. It was incubated at 37 °C for 18–24 h.

STEC and Salmonella spp. detection by real-time PCR

DNA was isolated from 1 ml of enrichment medium with InstaGene™ Matrix reagent for STEC and mericon™ DNA Bacteria reagent for *Salmonella* spp. investigation. The presence of STEC in the sample was determined in accordance with ISO/TS 13136 by real-time PCR (polymerase chain reaction) by determining the presence of stx1 and stx2 genes in the enriched sample. The presence of genetic material in the sample was determined with a set of mericon® Pathogen Detection reagents.

Detection of E.coli in enrichment medium

The analysis was carried out by weighing 25 ± 0.02 g of the sample in triplicate, placed in sterile filter bags and added 225 ml of BPW (buffered peptone

water). The sample was processed in a Stomacher® blender at 230 rpm for 30 s and incubated at 37 °C for 18–24 h. Samples were seeded on TBX and EMB medium and incubated at 44 °C and 37 °C for 24 h, respectively. The species affiliation of the grown colonies was determined by MALDI-TOF (matrix-assisted laser desorption and ionization time-of-flight) mass spectrometry using the MALDI Compass BioTyper™ 3 database (Bruker Daltonics).

Identification of bacteria with matrix laser desorption and ionization flight time mass spectrometry

Colonies typical of Enterobacteriaceae were frequently observed, and these bacteria were identified. The random colonies were transferred to a Nutrient agar (NA) plate and analyzed by matrix-assisted laser desorption and ionization time-of-flight (MALDI-TOF) mass spectrometry using the MALDI Compass BioTyper™ 3 database (Bruker Daltonics). Microbiological analyses were performed for the water used for rinsing and soaking, in accordance with the methods for determining safety and quality indicators LVS EN ISO 9308-1, LVS EN ISO 9308-2, LVS EN ISO 7899-2, LVS EN ISO 6222.

Statistical analyses

Data were analyzed using RStudio, mean and standard deviations were calculated for listed bacterial populations (log CFU per gram). An Anova analysis was used to determine whether there were a significant difference between ungerminated seeds contamination with Enterobacteriaceae and germinated seeds with a confidence level (P<0.05).

Results and Discussion

The target *E.coli*, *Salmonella spp.*, and STEC were not found in any samples, but Enterobacteriaceae was found in both seeds and sprouts. Enterobacteriaceae is known to be conditional food pathogens occurring in the human and animal intestinal tract but generally not associated with outbreaks of food-borne infections, including *Citrobacter braakii* and *Cronobacter sakazakii* (Iversen & Forsythe, 2004; Bergspica *et al.*, 2020). The predominant species, determined by MALDI-TOF mass spectrometry, were *Enterococcus faecium* (29%) and *Enterobacter cloacae* (46%). *Pantoea agglomerans* (9%) was detected in dry hemp

seeds. *Pantoea calida* (4%), *Lelliottia amnigena* (4%), *Klebsiella oxytoca* (4%) were found in soaked wheat and *Enterobacter hermannii* (4%) in broccoli sprouts. The percentage of Enterobacteriaceae species detected in first part is shown in Figure 1.

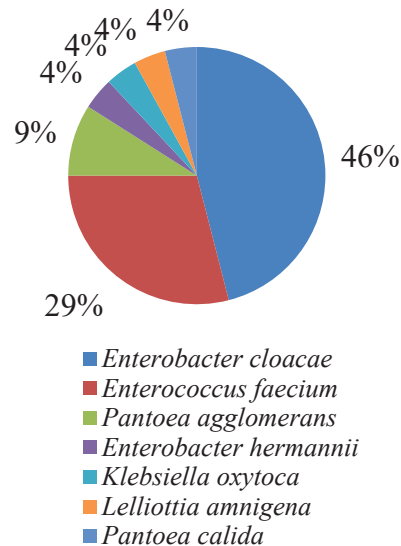


Figure 1. Species of Enterobacteriaceae detected in first part.

This study revealed that, similarly to the first part, *Salmonella spp.*, *E.coli* and STEC were not detected, but Enterobacteriaceae characteristic of soil and environmental bacteria were detected, similar to several Enterobacteriaceae species isolated in previous studies, such as *Enterobacter cloacae*, *Pantoea calida*, *Cronobacter sakazakii* from sprouts, salads, herbs, spices, and products ready to eat vegetables (Iversen & Forsythe, 2004) as well as described (Bergspica *et al.*, 2020). In dry seeds and grains, the number of Enterobacteriaceae increased from < 1 log CFU g⁻¹ to 2.0 log CFU g⁻¹ in wheat grain un radish seeds increased on average to 3.3 log CFU g⁻¹. After 3 days of germination, more than >6.0 log CFU g⁻¹ have already been detected for all germinated seed types. During the next 5 days of storage, up to 8.0 log CFU g⁻¹ were reached in most samples with

Table 1

Results of Enterobacteriaceae spp. log CFUg⁻¹

Seeds	dry	soaked	sprouts	stored for 5 days	stored for 8 days
Broccoli	0.00	1.30	>6.00	7.49	7.36
Wheat	2.00	3.23	>6.00	7.59	7.28
Alfalfa	0.00	3.18	>6.00	8.13	7.78
Radish	3.23	4.33	>6.00	7.29	7.27
Hemp	0.00	3.30	>6.00	Not tested	Not tested

no significant increase at ($P < 0.05$) in population on the day 8. The data obtained are similar to previous studies on alfalfa sprouts after 48 h of storage *Enterobacteriaceae* increased on average from 6.7 log CFU g⁻¹ to 8.0 log CFU g⁻¹ and listed *Enterobacteriaceae* averaged 6.0 log CFU g⁻¹ in ripe vegetables under storage conditions (6 °C for 72 hours) (Rotundo *et al.*, 2019). In second part, in samples, colonies of *Enterobacteriaceae*, similar to those in first part samples, *Enterobacter cloacae* was found in dry radish seeds, *Enterococcus faecium* – broccoli, hemp seed and wheat, while *Pantoea agglomerans* – alfalfa seeds. *Pantoea calida*, *Lelliottia amnigena*, *Klebsiella oxytoca* and *Enterobacter cloacae* were found in soaked wheat. Broccoli, radish and wheat sprouts *Enterobacter cloacae*, broccoli sprouts *Enterobacter hermannii*, radish sprouts *Klebsiella variicola*, but *Cronobacter sakazakii* were found in wheat and alfalfa sprouts. The percentage of *Enterobacteriaceae* colonies species is shown in Figure 2.

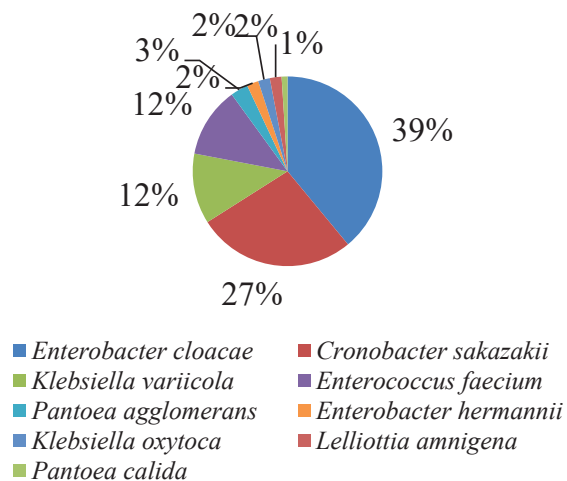


Figure 2. Species of *Enterobacteriaceae* colonies detected in second part.

Sprouts production is usually an intensive process using water to wash away dirt, pathogens and other substances from production, harvesting, storage and transport before soaking the seeds. During germination, the sprouts are rinsed every 12 hours to neutralize the heat released from seed germination (average temperature rises from 34 °C to 36 °C) and to prevent drying. Therefore, water quality can have a direct impact on the potential for pollution. In our study, the water used for rinsing and soaking was subjected to microbiological analyses in accordance with the methods for determining safety and quality indicators. The results correspond to the drinking water specified in the regulatory enactments Regulations of the Cabinet of Ministers of the Republic of Latvia No. 671/2017. In the early germination stage, germinated seeds provide nutrients to microorganisms. (Sikin *et*

al., 2013; Kim *et al.*, 2013; Koizumi *et al.*, 2008). These nutrients include low molecular weight metabolites consisting of carbohydrates, amino acids, flavonoids, sterols, and minerals that provide essential nutrients for bacterial cell growth (Cui *et al.*, 2018; Nelson, 1990; Schiltz *et al.*, 2015). The number of *Enterobacteriaceae* in sprouts was relatively high, but it is not used to indicate the microbiological quality of fresh fruits, vegetables and sprouts (Abadias *et al.*, 2008). Despite the large number of bacteria, these products showed no signs of spoilage. Sprouts are recognized as a relatively dangerous food, having the growth potential of pathogens in the germination process, as there is no specific step in the production process to reduce or destroy pathogens presented in untreated sprouts (NACMCF, 1999). High levels of micro-organisms do not necessarily pose public health problems. The presence and growth of pathogenic microorganisms is a concern. In the case of our analysed sprouts, it is recommended to wash the products before eating. However, high level of non-pathogenic micro-organisms in sprouts cannot be prevented or reduced by simple washing (Mohle-Boetani *et al.*, 2001). The obtained results coincide with similar studies found in the literature (Abadias *et al.*, 2008; Gabriel *et al.*, 2007; Martínez-Villaluenga *et al.*, 2008; Baenas *et al.*, 2017). Sprouts could be considered as relatively safe fresh products in terms of their microbiological contamination, as even after prolonged storage in a cold store, no pathogenic bacteria (Shiga toxin-producing *Escherichia coli* (STEC), *Salmonella spp*) were found. *Cronobacter spp* of *Enterobacteriaceae* family are new food-borne pathogen. Foods contaminated with *Cronobacter spp*. may pose a risk to infants or immunocompromised adults (Berthold-Pluta *et al.*, 2017). *Cronobacter spp*. are environmental bacteria and are found in water and soil, as well as in various foods, including dairy, meat, rice and other cereals, vegetables. In addition, *Cronobacter spp*. are often isolated from lettuce and vegetable salads (Berthold-Pluta *et al.*, 2017; Chenu & Cox, 2009; Iversen & Forsythe, 2003). The data of the study showed microbiological contamination of seeds and sprouted seeds, but do not indicate microbiological quality, because there are no binding standards in Latvia and Europe of *Enterobacteriaceae* for this type products.

Conclusions

The study showed that *E.coli*, STEC, *Salmonella spp*. were not detected in all types of seeds, grains and sprouts, but *Enterobacteriaceae* were detected in all samples. The highest microbiological contamination was observed in germinated seeds after three days of germination and during the next 5 days of storage in the range of 7.0 log CFU g⁻¹ to 8.13 log CFU g⁻¹ and

no increase in microbiological contamination was observed in the following days of storage. The lowest *Enterobacteriaceae* spp. count of $< 10 \log \text{CFU g}^{-1}$ was observed in dry seeds and soaked seeds increased from 10CFU g to $3.0 \log \text{CFU g}^{-1}$.

Among the bacteria of the species: *Enterobacteriaceae*, *Cronobacter sakazakii*, *Klebsiella variicola*, *Enterobacter cloacae*, *Klebsiella oxytoca*, *Enterococcus faecium*, *Lelliottia amnigena*, *Pantoea calida*, *Pantoea agglomerans* were identified, indicating that these products may be dangerous especially for children and people with low immunity. This indicates that the seeds and grains used were contaminated with the micro-organisms found during

primary production, as the germination process was in accordance with the requirements of good hygiene and good production and the water used was in accordance with drinking water.

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BEE DRONE BROOD HOMOGENATE CHEMICAL COMPOSITION, STABILIZATION AND APPLICATION: A REVIEW

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Abstract

The aim of this study was to review research findings and information about chemical composition and application of bee drone brood homogenate for food purposes. As the world's population grows, global warming and the impact of meat production on the ecosystem are increasingly being discussed. Various non-traditional sources of protein, such as insects and larvae, could replace traditional sources of meat protein in the future. Drone brood homogenate is obtained from honey bee drone larvae and is considered to be a very high value by-product of beekeeping. Scientific studies prove the prophylactic properties of drone brood homogenate to improve fertility and strengthen immunity against viral diseases. This product is rich in nutrients, amino acids, vitamins, minerals and hormones but a certain harvesting and processing technology is required to ensure that the product has a sufficient shelf life and an attractive appearance.

Key words: drone larvae, *Apilarnil*, honeybee products, bee pupae, brood homogenate, drone brood, drone milk.

Introduction

Honey and other bee products have been known for a very long time. These products are used as food and food supplements to improve health, because honey and other bee products are deemed to be prophylactic (Çelik *et al.*, 2019). Modern beekeeping is inconceivable without the presence of the *Varroa* mite (*Varroa destructor*). This parasite is a global problem for beekeepers, as it can lead to the death of a bee colony. Bees collect pollen and pollinate plants. Pollination is necessary for the plants to reproduce. The death of a bee colony affects the reproduction of plants, which is necessary for the maintenance of the ecosystem (Flores *et al.*, 2021). Today, the topical issue is the change in the use of varroasis control products, as *Varroa* mite in the world have become accustomed to synthetic pesticides, and bee colonies are weakening due to the increasing use of chemicals in agriculture (Kasiotis *et al.*, 2021). Many chemicals are banned in the European Union because they have a negative impact on the ecosystem. Harmful substances must not be allowed to enter beekeeping products. One of the most gentle ways to combat the spread of *Varroa* mites and other diseases is to remove bee drone larvae from the hive (Charrière *et al.*, 2003). Beekeepers on organic farms use this technique to control *Varroa* mites, because bee drone cells are attracted by a significantly higher number of mites than working bee cells. The development cycle of bee drone brood is longer than the development of working bees; therefore, *Varroa* mites develop in drone brood cells, because mites in working bee broods do not reach the maturity necessary for the production of offspring. Bee drone cells are 1.5 times larger in diameter than working bee cells (Yadav, Kumar, & Jat, 2017). The second reason why bee drone larvae are removed from the hive is to limit the number of drones for working bees. Bee drones eat a

significant amount of honey from the hive and cause losses of honey to beekeepers. Thus, bee drone brood homogenate is produced from drone larvae as a by-product of beekeeping.

Drone brood homogenate (DBH) is one of the bee products also known as *Apilarnil* discovered by Romanian beekeeper Mr. Nicolae V. Ilesiu. It is a homogeneous milky product with a sour taste, yellowish colour or sometimes a shade of grey (Barnutiu *et al.*, 2013; Sawczuk, Karpinska, & Milytk, 2019). The product is obtained by removing bee drone larvae from hives before closing the cells. In many literature sources, this product has been compared with royal jelly (Bogdanov, 2016; Çelik *et al.*, 2019; Sawczuk, Karpinska, & Milytk, 2019), which is milky secretion produced by worker honeybees for the purpose of feeding larvae and adult bee queens (Pavel *et al.*, 2011).

Bee drone larvae are rich in nutrients, vitamins and hormones. The aim of this study was to review the research findings and latest information about chemical composition and application of bee drone brood homogenate for food purposes.

Materials and Methods

The monographic method was used to summarise the research findings and latest information about bee drone brood homogenate for food purposes. Information was searched for in Science Direct, Scopus, Web of Science, Google Scholar. The following keywords were used in the selection of scientific literature: 'drone larvae', '*Apilarnil*', 'honeybee products', 'bee pupae', 'drone brood', 'drone milk' and 'brood homogenate'.

Results and Discussion

Harvesting of bee drone larva

Bees have different stages of development: egg, larva, pupa and imago (adult stage). Drones, the males

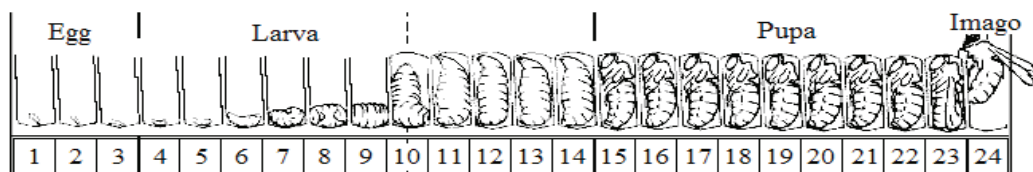


Figure 1. Stages of bee drone development (Modified by the authors, source: Development of the honey bees, 2021).

of the colony, are produced from unfertilized eggs. The developmental period of drones is 24 days (Yadav, Kumar, & Jat, 2017). From days 1 to 3, there is an egg (Figure 1). The size of a bee egg is approximately 1.5 mm (Woyke, 1998). From day 4 to day 14, there is the larva. From day 15 to day 23, there is the pupa. On day 24, an imago is formed from the pupa. On day 10, the working bees cap the larval cells of the drones. Bee drone larval harvesting should be planned at a certain stage in the life cycle of the bee drone. Day 10, when the drone cell is capped, it could be used to determine the age of the larva.

The day of the developmental cycle when it is harvested has a significant effect on larval composition. In the Romanian patent No. 0043842 B1 (Iliesiu, 1984), it is mentioned that bee drone larvae should be collected on day 10 of the development cycle. In patent RU No. 2402920 (Луцук, Дьяченко, & Белик, 2010), the larvae should be 9–10 days old. The stage of larva is characterised by a high nutritive value. The stage of prepupae begins from day 10 to day 14. In Patent US 2014/0323.014 A1, it is mentioned that the external feature of harvesting is when the prepupae are in a vertical position in the capped cells, with colourless or slightly yellowing eyelets without pigmentation (Trifonov *et al.*, 2014). The harvested larvae are then homogenized and filtered. Species, region, climatic conditions and flora are likely to have significant effects (Sawczuk, Karpinska, & Miltik, 2019).

Characteristics of drone brood homogenate chemical composition

Scientific studies provide information on protein levels depending on the age of the larvae (Grishina & Gengin, 2016). There is a tendency that as the age of the larva increases, the ratio of protein to larval

mass increases. The trend of increasing protein concentration depending on the stage of development can also be found in other scientific research (Ghosh, Jung, & Meyer-Rochow, 2016). The working bee’s pupa contains more protein than the larva, but the amount of carbohydrates decreases (Table 1).

Characteristics of DBH are presented in the Table 2, which shows the chemical composition for both fresh and lyophilised DBH and royal jelly. The composition of DBH is similar to royal jelly. Therefore, these products are often compared in research on bee products (Bogdanov, 2016). It is shown that the content of fructose and sucrose DBH is lower than in royal jelly. The chemical composition of DBH varies in different studies, but is within certain limits.

DBH was defined as a perspective alternative protein source if appropriate production, collection and processing is organized (Ulmer, Smetana, & Heinz, 2020). Geographical location and climate affect the composition of both royal jelly and larvae. The bee species could also have some effect. There are at least eight honeybee species in the world (Bees4life, 2021). European honeybee (*Apis mellifera*) is the most common worldwide. This specie is native to Europe, western Asia, and Africa. Proteins supplied in a lyophilised format are more stable for storage purposes. Potential degradation pathways for proteins: hydrolysis; oxidation; racemization; isomerization; denaturation; adsorption. Lyophilised proteins should not be exposed to atmospheric oxygen. Higher level than pH 8 should also be avoided. In pharmacy, it is recommended that lyophilised peptides and proteins should be stored at temperatures –20 °C or –80 °C to minimize degradation (Manning *et al.*, 2010).

Table 1

Approximate nutrients composition of larva, pupa and imago (adult) development stage, % of dry matter (Ghosh, Jung, & Meyer-Rochow, 2016)

Nutrients	Larva	Pupa	Imago (adult)
Protein	35.3	45.9	51
Fat	14.5	16	6.9
Carbohydrate	46.1	34.3	30.6
Ash	4.1	3.8	11.5

Table 2

Characteristics of fresh and lyophilised drone brood homogenate and royal jelly

Characteristics*	Drone brood homogenate		Royal jelly	
	fresh	lyophilised	fresh	lyophilised
pH	4.80–6.70	-	3.40–4.50	-
Acidity, ml 0.1N NaOH g ⁻¹	0.88–3.28	-	3.00–6.00	-
Water, %	65.0–76.4	3.0–4.5	60.0–70.0	2.7
Protein, %	4.6–12.0	32.0–52.4	9.0–18.0	27.0–41.0
Lipids, %	1.3–8.0	21.1–24.2	3.0–8.0	8.0–19.0
Carbohydrates, %	6.0–12.2	17.8–38.9	7.0–18.0	26.8
Ash, %	0.7–2.0	2.7–4.1	0.8–3.0	3.5
Energy value, kJ 100 g ⁻¹	503.3	1974.8–2097.9	381**	1525.9

‘-’ – information not found; *Data collected from Barnutiu *et al.*, 2013; Bogdanov, 2016; Isidorov, Bakier, & Stocki, 2016; Margaoan *et al.*, 2017; Sawczuk, Karpinska, & Milyk, 2019; Silici, 2019. **Calculated values.

Table 3

Comparison of hormone content in prepupae, bee drone brood and royal jelly

Hormones, nmol (100 g) ⁻¹	Prepupae with yellowing eyelets (10–14 days old)*	Fresh drone brood (9–11 days old)**	Fresh royal jelly**
Testosterone	0.292–0.322	0.310±0.015	0.200 ± 0.030
Progesterone	42.63–60.01	51.32 ± 8.69	4.61 ± 0.26
Prolactin	344.60–475.40	410.00 ± 65.40	70.80 ± 20.00
Estradiol (oestradiol)	431.20–847.90	677.60 ± 170.30	52.00 ± 6.00

*Data obtained from Trifonov *et al.*, 2014; Трифонов *et al.*, 2013; **Data obtained from Bogdanov, 2016.

Bee drone larvae contain much higher concentrations of **hormones** than royal jelly (Table 3). In Patent US 2014/0323.014 A1 it is mentioned that drone prepupae with yellowing eyelets guarantee hormone concentrations within certain limits (Trifonov *et al.*, 2014).

DBH can be used as a hormone preparation to improve fertility due to the significant hormone concentration of this product. Testosterone is the primary androgen responsible for the development and maintenance of male sexual characteristics. Progesterone is the dominant ovarian hormone with the function to prepare the uterus for embryo implantation. Prolactin stimulates the breasts to produce milk. Estradiol is the dominant ovarian hormone during the follicular (first) phase of the menstrual cycle (BPACNZ, 2013).

Amino acids perform a vital role in the development and maintenance of body. Humans can only synthesize 11 of the 20 important amino acids, which are necessary to make proteins. The other nine essential amino acids are obtained from the diet. Essential amino acids are involved in the biochemical processes of protein synthesis. Amino acid deficiency

impairs immune function and increases the susceptibility to diseases (Kubala, 2018; Wu, 2009). Bee drone larvae contain eight of nine essential amino acids: methionine, histidine, threonine, phenylalanine, isoleucine, valine, lysine, and leucine.

The concentration of amino acids in drone larvae is higher than in worker larvae, thus bee drone larvae are a better source of amino acids (Ghosh *et al.*, 2020; Ghosh, Jung, & Meyer-Rochow, 2016).

Drone brood homogenate is a rich source of **vitamins**. Vitamins are necessary for the normal growth, development and functioning of the body (Yaman *et al.*, 2021). The vitamin content is influenced by the diversity of plants used by bees to feed larvae and produce honey (Silici, 2019). DBH contains large amounts of water-soluble B vitamins, such as thiamine (B1), riboflavin (B2), niacin (B3), pantothenic acids (B5), pyridoxine (B6), biotin (B7), folic acid (B9), and cobalamin (B12) (Kistanova *et al.*, 2020; Silici, 2019). Vitamin C and choline are also found in DBH (Finke, 2005).

Important **minerals** in DBH are potassium (K), sodium (Na), calcium (Ca), magnesium (Mg) (Özkök, & Erdem, 2017). A study by Narumi (2004) found

zinc (Zn), iron (Fe), phosphorus (P), manganese (Mn), copper (Cu) and large amounts of selenium (Se) in honeybee brood. Selenium has not been found in other studies. This can be explained by the fact that selenium comes from the soil. Selenium is taken up from the ground by plants, which are pollinated by bees, so that selenium enters bee products (Li *et al.*, 2017; Zhao *et al.*, 2005).

Application of drone brood homogenate

Due to the chemical composition of bee drone larval homogenate, this product is widely used in veterinary medicine (Kistanova *et al.*, 2020; Shoinbayeva *et al.*, 2017), but few studies on the effects on human health have been found (Sidor, & Džugan, 2020). DBH is also discussed in apitherapy (Çelik *et al.*, 2019). Scientific studies prove the prophylactic properties of DBH to improve fertility and strengthen immunity against viral diseases.

Improving semen quality of stud rams (male sheep). Adding the preparation of DBH in the dosages of 15 mg kg⁻¹ of live body weight once per day increased the volume of ejaculate to 30.4%,

concentration of spermatozoa in the ejaculate up to 14.3%, mobility of spermatozoa increases to 9.2 points (Shoinbayeva *et al.*, 2017).

Improving fertility of female pigs. Gilts feed supplementation with the DBH promotes folliculogenesis in the ovaries of gilts at morphological and gene expression level (Kistanova *et al.*, 2020).

Stimulation of genital development. The raw DBH increased the relative organ weights of the glans penis, seminal vesicle and *levator ani* muscle in rats. It also increased the average prostate weight. The raw DBH was able to increase the relative organ weight of the uteri in immature female rats (Seres *et al.*, 2013).

The use of DBH for feeding male broilers (Yucel *et al.*, 2011) did not result in a significant increase in total body weight, but **improving laying efficiency** of hens was detected (Muravev & Kalachinskaya, 2014).

Immunity improvement to prevent viral diseases. Consumption of DBH with vitamin D₃ significantly increased the body's immunity to viral diseases. The patients received 1 tablet of the preparation 2 times a day during a three-month course.

Table 4

Methods for drone brood homogenate stabilisation

Method	Short description of processing parameters	Effect on product quality during its storage	References
Freezing	Brood in the combs, at -20 °C	Without severe change of taste can be stored for 6 months	Jensen <i>et al.</i> , 2019
	Cleaned brood in vacuum-sealed bags, at -20 °C	Without severe change of taste can be stored for 10 months	Jensen <i>et al.</i> , 2019
Freeze drying (lyophilisation)	The lyophilised powder was prepared by freeze drying to the temperature of -5 °C, under residual pressure of 0.03 mmHg for 24 h	The product retained the original biological properties	Shoinbayeva <i>et al.</i> , 2017
	The freezing is done rapidly in temperatures of -50 °C and -80 °C, primary drying at pressure of a few millibars, secondary drying can even be above 0 °C	Lyophilised DBH obtained moisture content of 1% to 4% and retained the original biological properties	Berk, 2013; Bogdanov, 2016
Mixing with honey or sugars	Mixed with honey (not more than 1-2% of brood)	Mixtures can be stored for 6 months at room temperature	Bogdanov, 2016; Бурмистрова <i>et al.</i> , 2008
	Adsorption on glucose-lactose (1:1) and dried until 4% moisture content	Can be stored at 4-6 °C up to 2 years	Bogdanov, 2016; Бурмистрова <i>et al.</i> , 2008
	Mixed with lactose and glucose, then drying is performed with IR-rays during 4 hours at 42-45 °C in the "heating-cooling" pulse mode	Moisture content decrease and biologically active substances preservation, reduction of microbiological contamination and decay prevention	Чекрыга, Волончук, & Левин, 2012
Adding ethanol	DBH combined with 40% and 70% ethyl alcohol with added antioxidant	Obtained stable tincture which has an extended shelf life and retains its biological activity of the components for 2 years	Будникова, 2011; Гашиш <i>et al.</i> , 2018

There were no cases of acute respiratory disease or influenza in the patients during the autumn and winter period (Strukov *et al.*, 2016).

Processing and preservation of drone brood

Drone larvae should be harvested together with the combs. Removal from the hive should be done carefully so as not to injure the larvae. Both open and capped larvae will stay alive at room temperature for a few hours after removal from hive (Jensen *et al.*, 2019). Other studies suggest that larvae should be refrigerated immediately after cutting out from the combs. Freezing, drying, boiling or frying should be completed less than 24 hours after collection of larvae to avoid any spoilage. Insect proteins decay much faster than those of beef, pork, lamb or chicken (Bogdanov, 2011; Krell, 1996). Rapid larval deterioration may begin after homogenisation, thus DBH requires immediate processing under strict hygiene requirements. One of the solutions used by beekeepers is to freeze DBH at -20 °C or mix it with honey in certain proportions (Hroshovy *et al.*, 2021; Isidorov, Bakier, & Stocki, 2016). Sugar helps to prevent or slow down the growth of bacteria, moulds and yeast in food (SNRC, 2021). Honey, sucrose, lactose or glucose can be used as preservatives (Митрофанов *et al.*, 2015). Different stabilization technologies can be used to efficiently extend the shelf life of DBH (Table 4).

Freeze drying is a process in which water is removed from a product after it is frozen and placed under a vacuum, allowing the ice to change directly from solid to vapour without passing through a liquid phase (FDA, 2014). The absence of water prevents microbial growth and chemical changes leading to deterioration of product. Lyophilised DBH kept the original biological properties, measured by its immunomodulating, spleen and T-cell stimulating properties (Bogdanov, 2016). Freeze drying did not reduce DBH hormone levels (Sidor & Džugan, 2020). The maximum allowable drying temperature must not exceed 45 °C, as this will inactivate the hormones and biological activity in the product (Будникова, 2011; Корж, 2009). Freeze drying could be the most suitable drying technology for DBH to improve the shelf life of the product. Spray drying could also be used, but elevated temperatures can degrade product quality - the product loses hormones and vitamins.

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Most of the consumers avoid eating insects, larvae or worms, which could be one of the alternative sources of protein in the future (Higa *et al.*, 2020). Encapsulated DBH would be more attractive and convenient for consumers.

DBH is a product rich in nutrients, minerals and hormones, and its effective use is possible through certain harvesting and processing technologies. The shelf life can be extended by freezing and drying, and additives can be added. The processing technology used must not impair the valuable composition of the product. The resulting product must be acceptable and safe for the consumers. In the future, DBH could be widely produced as a food supplement in Latvia as well, but extensive research is needed on the processing and chemical composition of DBH obtained in the Baltic region and its impact on human health and safety.

Conclusions

Drone brood homogenate (DBH) is considered to be a very high value by-product of beekeeping, which can bring additional income to beekeepers if it is properly processed. Geographical location, climate, species and stage of development affect both the composition of the royal jelly and the larvae. Bees feed drone larvae with royal jelly, but DBH is made from drone larvae, so the composition of these two beekeeping products is similar, but DBH has elevated levels of sex hormones. In order for DBH to obtain the highest hormone concentration, the collection of drone larvae should be performed on days 10 to 14 of the developmental stage, observing the external feature: the prepupae in a vertical position in the capped cells, with colourless or slightly yellowing eyelets without pigmentation. Scientific studies show that the use of DBH has health benefits, including improved fertility of animals, strengthening immunity to prevent viral diseases. DBH is a product rich in nutrients, amino acids, vitamins, minerals and hormones but a certain harvesting and processing technology is required to ensure that the product has a sufficient shelf life and an attractive appearance. DBH was defined as a perspective alternative protein source, which could replace pork or beef in the future.

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TOTAL PHENOLIC CONTENT AND ANTIRADICAL ACTIVITY OF HONEY POWDERS

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Abstract

Honey powders could be an innovative and attractive substitutes to liquid honey. The production of honey powders would allow to expand honey's usage in food industry, cosmetics and pharmaceuticals. In this research, freeze drying method was performed to obtain honey powder samples. Overall, 4 different formulations were prepared to obtain the powder samples. The aim of the research was to determine the total phenolic content and antiradical activity of the freeze-dried honey powder samples by spectrophotometric method. The content of total phenolics in the samples ranged from 92 to 146 mg GAE 100 g⁻¹ of dry matter. Antiradical activity was measured with DPPH radical scavengers, and the IC₅₀ results ranged from 6 to 12 mg mL⁻¹.

Key words: honey powder, freeze drying, antiradical activity, total phenolic content.

Abbreviations: H, honey; MD, maltodextrin; MN, mannitol; DPPH, 2,2-diphenyl-1-picrylhydrazyl; IC₅₀, half maximal inhibitory concentration; AA, antiradical activity; GAE, gallic acid equivalent.

Introduction

Honey is a naturally sweet food stuff, which has high nutritional value and its therapeutic properties are well-known over the centuries. Honey consists of 200 chemical compounds (Bueno-Costa *et al.*, 2016). The wide range of different substances are found in honey such as enzymes, amino acids, organic acids, monosaccharides, different phenolic compounds (Tezcan *et al.*, 2011; Da Silva *et al.*, 2016). Noteworthy that the chemical profile of honey depends on many factors, for instance, climate, botanical and geographical origin. Honey is classified in different types, which are based on their geographical origin or floral source (Sakač *et al.*, 2018). The phenolic profile of honey is mostly the same, but the concentrations of phenolic compounds in different type are variant (Badolato *et al.*, 2017). Phenolic compounds such as phenolic acids and flavonoids are natural antioxidants (da Silva *et al.*, 2013). Antioxidants have a significant role in human health (Mithul Aravind *et al.*, 2021), they protect the body cells from free radicals. Free radicals are very reactive and have a tendency to react with biomolecules, which could result in serious cell damages (Zheng *et al.*, 2020).

The production of powdered honey is an innovative approach to expand the application of honey in food industry, pharmaceutical industry. Longer shelf life and expanded usage in food processing (Tong *et al.*, 2010; Kılınc & Demir, 2017; Tomczyk *et al.*, 2020) are a few of advantages of powdered honey, which present powdered honey as an attractive substitute to natural honey. The interest of production of honey powder among food scientists has been increased (Samborska, 2019). Different drying methods (Nurhadi *et al.*, 2012; Sramek *et al.*, 2016; Samborska *et al.*, 2017) have been studied for obtaining honey powder. As honey is a sugar-rich food product (Muzaffar, 2015), its drying is very challenging. The main issue is that sugar-rich

food products during drying can make lumps or syrup (Bhandari *et al.*, 1997). This issue mainly can be prevented by adding different drying aids or carriers to increase the glass temperature of drying particles (Shi *et al.*, 2013). Freeze-drying among all drying methods, which are recently performed for obtaining high quality honey powder, is not very common (Ganaie *et al.*, 2021). The main reason of that is a long production time, which expands the cost of production. Nevertheless, freeze-drying is bioactive compounds preserving drying technique (Ranieri *et al.*, 2017; Prosapio & Norton, 2018).

The phenolic profile of honey and other food products can be evaluated by different analytical techniques (Chan *et al.*, 2013; Zhu *et al.*, 2019; Tian *et al.*, 2021). Spectrophotometric method is one of the most popular analytical methods due to its low cost, simplicity, rapidness. Total phenolics content is commonly determined using Folin-Ciocalteu reagent. The method is easy to modify and allows to detect total phenolic content in a wide range of products (Kek *et al.*, 2014; Paradiso *et al.*, 2016; Hinojosa-Nogueira *et al.*, 2020). Antiradical activity of different food products is examined by the DPPH test (Marinova & Batchvarov, 2011; Naji *et al.*, 2020).

The production of honey powder involves thermal treatment and could negatively affect the quality of honey by, for example, decreasing enzyme activity (Tosi *et al.*, 2008; Sramek *et al.*, 2016; Samborska *et al.*, 2017), increasing the concentration of 5-hydroxymethylfurfural (Pasiak *et al.*, 2017; Kanar & Mazl, 2019).

As phenolic compounds are sensitive to temperature changes (Molaveisi *et al.*, 2019; Samborska *et al.*, 2019), it is important to examine honey powder. The aim of the research was to determine the total phenolic content and antiradical activity of the freeze-dried honey powder samples by spectrophotometric method.

Materials and Methods

The experimental work of study took place at the Scientific laboratory of Natural compounds at the Department of Chemistry, Faculty of Food Technology, Latvia University of Life Sciences and Technologies.

Buckwheat honey was purchased from a local beekeeper. Buckwheat honey was harvested in 2019. The beehives were placed in Jelgava district, the southern-central part of Latvia.

Maltodextrin (STAR-DRI® 10 NG, TALE & LYLE, USA) was delivered by Latvian company (BANG & BONSOMER LATVIA, Rīga, Latvia). Dextrose equivalent (DE) of maltodextrin was 10.4. Moisture content, according to the certificate given by the company, was 4.3%. Mannitol was purchased from Riedel-de Haën and moisture content was 0.5%. (Honeywell, Germany).

Freeze-drying of honey solution

Four different 30% aqueous solutions of honey with mannitol and maltodextrin were prepared for the experiments.

The proportions of honey and carriers in feed solutions are shown in Table 1.

Table 1

Proportion of honey and carrier in feed solution

Carrier	Ratio (honey: carrier)
Mannitol	1:1
Maltodextrin	1:1
Mannitol	1:2
Maltodextrin	1:2

The solutions were poured into plastic freezer containers. The height of solution layer in each container was approximately one centimetre. The containers were kept in the freezer at -20 ± 1 °C for 3 hours. Drying of frozen samples were performed as described by Keke (Keke & Cinkmanis, 2020). The obtained freeze-dried honey samples each were grinded into powder by porcelain mortar and pestle. The powder samples were collected in polyethylene bags and stored at $+20$ °C temperature in dark and dry place until further analysis.

Detection of moisture content

Determination of moisture content was carried out using a moisture analyzer AND MX-50 (A&D Company, Limited, Japan). The moisture content of samples were evaluated using the method described by Keke (Keke & Cinkmanis, 2020). The software 'WinCT-Moisture' was used for the data recording.

Detection of total phenolics

The content of total phenolics of the obtained honey powders and buckwheat honey were evaluated

by the Folin-Ciocalteu method. The honey powder samples and honey were dissolved in deionized water. The concentration of each prepared solutions was 0.1 g mL^{-1} . Then 2.5 mL of 0.2 M Folin-Ciocalteu reagent (Sigma Aldrich®, Germany) were added to 0.5 mL of prepared solutions and mixed. After 5 minutes 2 mL of 7.5% Na_2CO_3 solution were added to the mixture and mixed together. The reaction solution was stored at $+20$ °C temperature in the dark for 2 hours. After incubation the content of total phenolics was determined by spectrophotometer Jenway 6405 UV/Vis (JENWAY, the U.K.). The absorbance of the samples was measured at 760 nm. Deionized water was used as blank solution. The results were expressed as gallic acid equivalents $\text{mg GAE } 100 \text{ g}^{-1}$ dry matter (Cinkmanis, Dimins, & Mikelsone, 2017).

Detection of antiradical activity

The antiradical activity of the samples was determined using 2,2-diphenyl-1-picrylhydrazyl radical (DPPH). The obtained powders and buckwheat honey were dissolved in deionized water at concentrations ranging from 2 to 14 mg mL^{-1} . And 3.5 mL of prepared solution was well-mixed with 1.5 mL of 0.1 mM DPPH (Sigma Aldrich®, Germany) solution. The reaction solution was stored at $+20$ °C temperature in the dark for 30 minutes. After incubation the determination of antiradical activity was performed by spectrophotometer Jenway 6405 UV/Vis (JENWAY, the U.K.). The absorbance of the samples was measured at 515 nm. The results were expressed as the percentage of antiradical activity (AA). The antioxidant activity was calculated according to the following formula:

$$AA = \left(\frac{ABS_{control} - ABS_{sample}}{ABS_{control}} \right) \times 100 \quad (1)$$

As blank solution, dissolved honey powder solutions at the same concentrations as previously were described and 3.5 mL of methanol were used. The control solution consisted of 3.5 mL of methanol (Sharlab S.L., Spain) and 1.5 mL of 0.1 mM DPPH solution. The IC_{50} values were calculated by linear regression of plots, where the concentration of prepared solutions were represented on the abscissa, and the antiradical activity of prepared solutions was represented on the ordinate (Pontis *et al.*, 2014; Cinkmanis, Dimins, & Mikelsone, 2017).

Statistical analysis

The assays were repeated three times, and the results were expressed as mean values \pm standard deviation (SD).

One-way analysis of variance (ANOVA) and Tukey's test ($p < 0.05$) were used to verify statistical differences. Analysis were performed by Microsoft 365 Excel.

Table 2

Moisture content and IC₅₀ value in the analysed samples

Carrier	Ratio (honey: carrier)	Moisture content, %	IC ₅₀ , mg mL ⁻¹
Mannitol	1:1	4.5±0.2	6±1
	1:2	3.5±0.2	8±2
Maltodextrin	1:1	5.6±0.1	10±1
	1:2	3.3±0.2	12±1

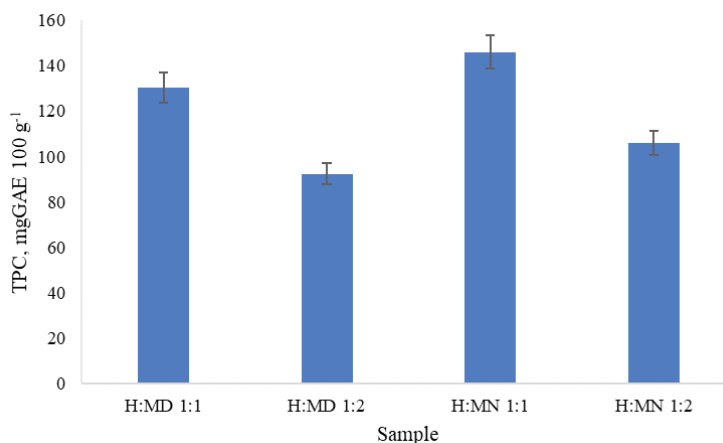


Figure 1. Total phenolic content in honey: maltodextrin 1:1 (H:MD 1:1), honey: maltodextrin 1:2 (H:MD 1:2), honey: mannitol 1:1 (H:MN 1:1), honey: mannitol 1:2 (H:MN 1:2) powder samples.

Results and Discussion

Freeze-drying method was performed to obtain honey powder samples. This dehydration technique is well-known in pharmaceuticals as bioactive compounds preserving drying method (Scutellà *et al.*, 2018). Overall, four formulations were prepared to obtain honey powders. The moisture content in the samples varied from 3.3 to 5.6%. The moisture content in each analysed sample is shown in Table 2.

Maltodextrin and mannitol both are widely used carriers. Maltodextrin is commonly used for drying experiments in food industry (Siccama *et al.*, 2021; Teo *et al.*, 2021). It is usually added during spray drying process to increase the glass transition temperature of drying agent (Hebbar, Rastogi & Subramanian, 2008). Mannitol is a popular non-hygroscopic additive in freeze-drying formulations for pharmaceutical experiments (Kaialy & Nokhodchi, 2015). Mannitol is sugar alcohol, which is used for providing a stable matrix structure during freeze-drying (Mehta *et al.*, 2013).

Total phenolic content in the freeze-dried honey powder samples and fresh buckwheat honey was determined by Folin–Ciocalteu method. The method is based on the reaction between the Folin–Ciocalteu reagent and phenolic compounds, which forms a

coloured complex. Spectrophotometric method was used to measure the absorbance of coloured complex. The measured absorbance data was used to quantify total phenolic content in the samples. The total phenolic content of the samples ranged from 92 to 146 mg GAE 100 g⁻¹ dry matter. High concentrations of phenolics were detected in the samples, where the ratio of honey and carrier was 1:1 (Figure 1). The sample, which contained mannitol, showed the highest content of total phenolics.

Difference in the content of total phenolic compounds in the samples, where the proportion of honey and carrier was 1:2, was not statistically significant ($p > 0.05$). Total phenolic content was analysed in buckwheat honey, which was used for drying experiments. The content of total phenolic in the honey sample was 175 mg GAE 100 g⁻¹ dry matter. Statistically the difference in values between buckwheat honey and obtained dry food products was not significant ($p > 0.05$). Samborska and co-workers (Samborska *et al.*, 2019) also used maltodextrin as carrier in their spray drying experiments to obtain honey powder. In the research, the scientists used different formulations of rapeseed honey and maltodextrin. The highest content of total phenolics was detected in the sample, where honey and maltodextrin ratio was

80:20. In their case, spray drying with dehumidified air was performed to obtain honey powder. The determined value of total phenolics was 78.5 ± 3.7 mg GAE 100 g^{-1} dry matter (Samborska *et al.*, 2019).

Antiradical activity was examined using 2,2-diphenyl-1-picrylhydrazyl (DPPH) reagent, which in reaction with antioxidants forms a yellow solution, which is the colour of the reduced form of DPPH. The absorbance of the coloured solutions were measured and used to determine the antiradical activity of analysed samples. The antiradical activity of the analysed samples were expressed as IC_{50} value. The IC_{50} value shows the ability of sample to inhibit 50% of free radicals. The lower IC_{50} value of the sample is detected, the greater ability it has to neutralize free radicals. The obtained IC_{50} values ranged from 6 to 12 mg mL^{-1} (Table 2). The powders, which contained mannitol, showed the lowest IC_{50} values, and they had a greater ability to neutralize free radicals than the powders, which contained maltodextrin. The reason, why mannitol showed a greater ability to neutralize DPPH, is that mannitol also has antioxidant properties (den Hartog *et al.*, 2010). The IC_{50} value of used buckwheat honey was $3 \pm 2 \text{ mg mL}^{-1}$. Comparing both used carriers and their influence to antiradical activity in powders, maltodextrin showed statistically significant influence to the antiradical activity ($p < 0.05$), but mannitol's influence was not statistically significant ($p > 0.05$).

The freeze-drying process involves very low temperatures and pressure, which allow to protect temperature sensitive phenolic compounds from degradation (Kaialy & Nokhodchi, 2015). As honey is a hygroscopic food product, it is difficult to obtain dehydrated honey without adding carrier materials (Ganaie *et al.*, 2021). Obtaining dehydrated honey samples by this method was not time efficient and

should be modified to optimize drying time and increase the content of honey. Unfortunately, to authors' knowledge there are not scientific publications on obtaining honey powder, where mannitol would be used as a carrier. The experiments showed that mannitol could be used as carrier material for food drying experiments. The application of mannitol as a carrier material in drying experiments might be limited due to its laxative effect. The laxative effect of mannitol might be observed if the daily intake of mannitol exceeds 20 g (Grembecka, 2015). There are many studies (Mooradian *et al.*, 2017; Sahin *et al.*, 2018), where mannitol and other sugar alcohols have been investigated and considered as sucrose substitutes. Honey powder is a relatively new food product, which still needs to be investigated. The further investigations of honey powder would allow to present it to food consumers as an innovative and examined dry food product.

Conclusions

Freeze-drying could be applied as an alternative dehydrating method for obtaining honey-rich powder. Total phenolic content and antiradical activity in the prepared honey powders depend on honey content in the experimental formulations. The obtained powdered samples, which contained honey and mannitol, showed the highest content of total phenolic compounds than the samples, which contained honey and maltodextrin at the same ratio.

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ORGANIZATION OF THE FOOD DISTRIBUTION SYSTEM IN THE CONTEXT OF SUSTAINABILITY ACCORDING TO INSTITUTIONAL DIMENSION

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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 food distribution system is one of the essential activities ensuring the company's competitiveness in food sector, which ensures timely production and quality of customer service. Nevertheless, the compliance of the company's distribution system with the principles of sustainable development is a major challenge for most companies. The company's goal of sustainable development must not forget the main goal - the pursuit of profit; therefore, it is necessary to clearly define the main strategic activities, criteria and evaluation system that would help identify the most suitable solutions for the company to meet both sustainability and profitability expectations. To this end, it is necessary to integrate the institutional dimension and to analyze the food distribution system at the strategic level.

The paper analyses the impact of sustainable development on food distribution system to determine which activities are most responsive to sustainable development and company's goals. The main purpose of the model, presented in the paper, is to help the business sector integrate sustainable development principles effectively in food distribution system, considering the significance of ongoing factors in the system for sustainable development. As study result presented evaluation of international company food distribution system in the context of sustainability according to institutional dimension by identifying value of criteria's and evaluation main activities in a company distribution system.

Key words: distribution system, sustainable development, institutional dimension, Simple Additive Weighting (SAW).

Introduction

In the modern concept of sustainable development, the institutional dimension is rarely singled out as a separate component of sustainable development. Certain aspects of this dimension are included in the economic, social or environmental, technological fields, so it is very difficult to identify a clear dividing line between all the components of sustainable development. Research has shown that a company's social, economic, environmental issues can be directly integrated only at the institutional level, so the concept of institutional dimension was proposed more than a decade ago (Spangenberg, 2014). Institutional importance has also been emphasized by other authors (Bleischwitz, 2003; Baumgartner & Rauter, 2017), who argue that it is managers who are responsible for political decision-making in an organization, eco-efficient innovation, performance control, and regulatory mechanisms for the social well-being of its members and society.

The institutional dimension can be analyzed from several aspects of external interaction - the interaction of the enterprise as an entity with state and public institutions or as an internal interaction by involving the integration of the principles of sustainable development into the management of the company's activities. Strategic management is a specific and distinctive feature of any company. This article analyzes the institutional dimension through the prism of internal interaction by modeling the institutional

dimension actions that unfold in the food distribution system strategy development model.

Engert *et al.* (2016) believe that the institutional dimension at the enterprise level could coordinate other dimensions of sustainable development and thus accelerate the implementation of sustainable development provisions in the business environment. By exercising ethical and moral principles, companies not only exercise the powers, rights and responsibilities conferred on them by government, but also create an environment in which sustainable development initiatives are launched.

In order to identify the institutional dimension of the food distribution system in the sustainable development strategy model, it is necessary to identify the main components of strategy development and management in the business sector enterprise in organizing food distribution system.

Analyzing the company's goals and their relationship with sustainable development Danciu (2013) states that sustainable development should be perceived as the company's most important goal, but this contradicts the basic business principles, because the company's priority goal is to make a profit. Thus, if the implementation of the sustainable development strategy starts to contradict the profitability of the company, there would be a contradiction regarding the need and possibilities of sustainable development integrity in the process management of the company. Results can only be achieved by combining these two

groups of objectives and integrating sustainability into the company's strategy, but not by developing a separate sustainable development strategy. It should be noted that when analyzing the expression of sustainable development at the level of company strategy development, the institutional dimension becomes equivalent to other sustainable development dimensions and must be integrated into the entire process management of the company.

Baumgartner (2014); Mohammed, Muff (2015) argue that the key question for modern business is not why a firm should be sustainable, but how a firm can be sustainable. Taylor (2013) emphasizes the integration of sustainability into the vision, mission and value system. The author proposes to integrate the principles of sustainable development in a systematic way, starting from the vision and goals, gradually moving to planning, decision-making and strategy adjustment.

Problem of the research. The main goal of business enterprises is to make a profit, but in the face of globalization, the sustainable development of enterprises is playing an increasingly important role. Therefore, a clear problematic question arises - how can a company properly integrate the principles of sustainable development at the strategic level in order to achieve operational efficiency of the food distribution system while increasing the company's sustainability?

Aim of the research. To develop and test in practice a selection of alternative decisions of the strategy model of food distribution system in the context of the institutional dimension using multi-criteria evaluation method.

Objectives of the research:

- to review the basic theoretical aspects of organizing food distribution logistic system in the context of institutional dimension;
- to create a model and an evaluation tool of strategy selection according to the expression of the institutional dimension in the food distribution system;
- to test in practice the suitability of the tool developed in a food distribution company in the context of institutional dimension.

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.

The selection of strategy must take into account the impact of its implementation in increasing the company's ability to meet the requirements and expectations of stakeholders. With regard to the content

of this component, it is proposed to choose a strategy based on the results of the analysis and evaluation of strategic alternatives according to the criteria (Matwiejczuk, 2013; Lichocik & Sadowski, 2013; Saufa *et al.*, 2016). This issue should be considered from a slightly different perspective, suggesting that the results of the analysis and evaluation of the institution's SWOT and its operational problems be taken into account in the design and adoption of the strategy. In addition, when analyzing and evaluating strategic alternatives, they suggest taking into account the potential of the company resources and the response of the institution's stakeholders to the implementation of the strategy. Hadas (2014) reveals the essence of decision-making and decision-making in implementing strategic goals, provides strategy selection according to an integrated criteria (acceptability to the institution's stakeholders, decision-makers and their implementers, compatibility with the institution's mission, values and philosophy).

Summarizing the various scientific opinions, it can be stated that most of them emphasize the need to analyze and evaluate strategic alternatives according to various criteria. The synthesis of diversity in terms of the set of tasks of the component under consideration and their content allows defining the following generalized content of the proposed component of the institution's strategic planning model: compilation of strategic alternatives, the results of the analysis and evaluation.

Materials and Methods

In order to more clearly identify and systematize the authors' information, a model for the development of a sustainable strategy of the food distribution system is formed, which is formed considering the expression of the institutional dimension in the strategy development phase. The content of strategic planning for sustainable development consists of different activities from analysis till searching for improvement opportunities (Figure 1).

The developed model is of a flexible type in order to achieve continuous process management and improvement opportunities.

By developing the strategic management of enterprises and integrating the main components of sustainable development, the model is constructed in order to reveal the main strategic decisions in the context of institutional dimension.

The model is conceptual and starts with classical strategic decisions and management. In order to reveal the institutional dimension in the preparation of the strategy, the first step is the analysis of the main factors that are implemented in the company under the institutional dimension.

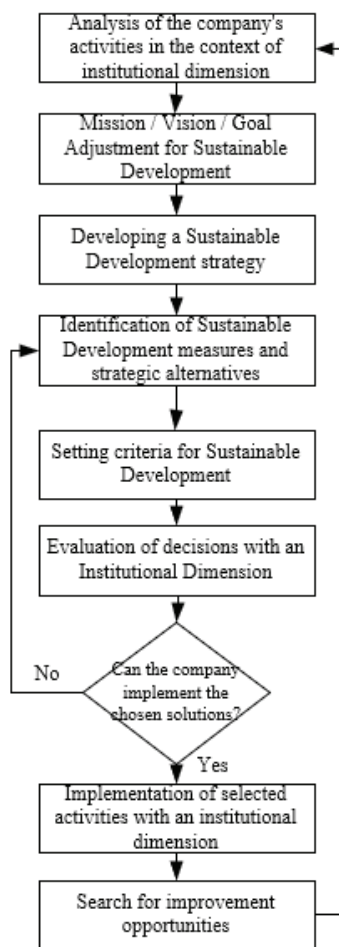


Figure 1. Model of food distribution system development in the context of institutional dimension.

After clearly defining the company’s goal, vision, mission, objectives and the possibilities of their links with sustainable development, the process of identifying and evaluating sustainable development measures / strategic alternatives is transitioned.

Once alternatives to strategic solutions have been developed (Table 1), they need to be compared and evaluated. This requires evaluation criteria. A criterion is defined in the literature as a measure of evaluation, a quantity expressed quantitatively or qualitatively that provides information necessary for decision-making. In summary, a criterion is an indicator by which an assessment is made and the information obtained during this process is used to justify decisions.

In order to evaluate the alternatives of the selected strategy of food distribution systems, it is necessary to provide evaluation criteria on the basis of which this would be done.

Researchers identify various criteria for strategic decisions, but the most common recurring ones in the distribution system are twelve: *compliance with the strategic goals of the company; flexibility of strategic decision; advantage of a strategic decision over competitors; adequacy of human resources; compatibility with economic factors; compatibility with social factors; compatibility with technological factors; compatibility with ecological factors; adequacy of financial resources; appropriateness of the payback period; value to the consumer; compliance of the strategic alternative with the organizational culture* (Sullivan, 2018; Lee, 2012; Weijers *et al.*, 2012; Shaaban & Scheffran, 2017). The criteria analyze the external and internal factors that have the greatest impact on the company’s strategic decisions.

Table 1
Expression of strategic distribution alternatives in the context of institutional dimension (Taylor, 2013; Dornfeld *et al.*, 2013; Hall *et al.*, 2012)

Types of logistics process management solutions	Alternatives to logistics process activities
Customers selection	Own cargo warehousing
	Cargo warehousing for one customer
	Cargo warehousing for more than one customer
	Mixed
Selection of stored cargo by expiration date	Long validity
	Short validity
	Mixed
Selection of stored cargo according to special requirements	Temperature regulation
	Reservoir
	Standard
Provision of additional storage services	Packing
	Sorting
	Cutting

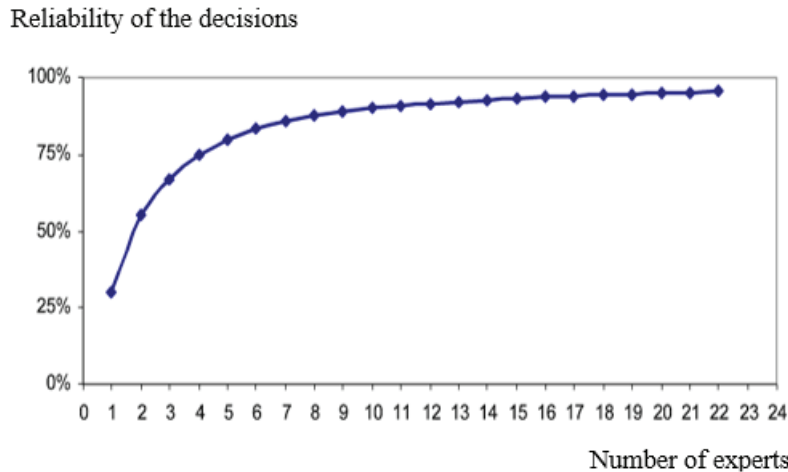


Figure 2. The decision reliability dependence on number of experts (Wright *et al.*, 2019).

Once strategic alternatives have been identified, there is likelihood that the selected alternatives may not be appropriate or feasible because they do not meet the company’s current financial, social or technological capabilities. Analysis and integration of the goal and objectives with the sustainable development until the best consensus is found.

Methods for evaluation. In order to perform an alternative assessment, it is necessary to choose the most appropriate method for evaluation. The management of the activities of companies and the activities of the food distribution system is attributable to social phenomena. Multi-criteria assessment methods are widely used for the analysis of this type of phenomena and for making managerial decisions.

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 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.

In the search for opportunities, there is a need to identify and create a list of alternatives in order to evaluate and select most suitable ones based on a sustainability. Significance of the factors has to be determined by expert method. The number of experts influences reliability of final decision. We suggest using the scheme (Figure 2) for determination best number of experts, according to which we think that 6–7 experts are enough for a reliable decision.

Expert requirements also need to be established: distribution experience, understanding of sustainability, achievements in these areas.

For the study, experts were selected from a leading international capital company providing food

distribution services. The group of companies operates in 13 countries around the world and has 150 divisions. The total warehouse area is 1.2 million square meters. There are three divisions of the company in Lithuania. The company’s strategy clearly reveals sustainable development, social responsibility and other definitions related to sustainable development. One of the company’s areas of activity is the organization of food distribution system. All experts have more than 5 years’ experience in logistic sector, and they have been working with adaptation of main principles of sustainability in logistics for more than 3 years.

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):

$$W_i = \frac{\sum_{e=1}^n W_{ie}}{n}, \quad i = \overline{1, m} \quad (1)$$

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 assessment of factors value according to possibilities for sustainability have to be calculated by following (*Simple Additive Weighting – SAW*) formula (Drejeris & Oželiene, 2019):

$$T = \sum_{i=1}^j \eta_i K_{ij}, \tag{4}$$

Where *T* – total value of factors according to possibilities to be sustainable, *K* – value of every factor.

Results and Discussion

For the study, an individual expert survey method was used under Figure No. 2. A questionnaire was developed for 6 experts from international company to assess the relevance of the criteria to the food distribution system. The results of the evaluation of experts are presented in Table 2. The experts gave the highest rank to the compatibility with the company's strategic goals (significance 0.12), and the lowest to the compliance of the strategic alternative with the organizational culture (significance 0.05).

Once the significance of the criteria has been established, an assessment of alternatives to the food distribution system is carried out. Experts among all 12 criteria had to split 100 points under criteria

important to food distribution system in context of sustainability in institution dimension. Results were given in coefficient format.

Under these criteria's, for food distribution system strategy creation need in total, the study evaluates 13 alternatives from 4 different groups according to 12 established criteria (Table 3). The nature of the selected criteria corresponds to the characteristics of the objects being assessed (Awasthi *et al.*, 2018).

The more alternatives included in the distribution system management, the clearer the results in order to make the most appropriate decisions for the company. We have selected only the possible main strategic alternatives, which are typical for food distribution system and possible to be specified if necessary. Such an option will really increase the flexibility of the strategy.

Summarizing the evaluation of food distribution system alternatives in the context of the institutional dimension, it can be stated that the most appropriate distribution strategy for a company is: to provide services, which can be provided to more than one customer; focus on the storage of long-life products; implement storage in a standard warehouse; provide additional packaging and sorting services. The company can also identify other strategic decisions which can stem from special needs and activities of the company for the evaluation and identification of the most appropriate evaluation system and methodology.

Table 2

The results of the expert evaluation to determine the significance of the criteria

Criteria	Expert						Significance
	E1	E2	E3	E4	E5	E6	
Consistency with the company's strategic objectives	0.12	0.13	0.12	0.11	0.12	0.11	0.12
flexibility of strategic decision	0.06	0.06	0.05	0.07	0.07	0.05	0.06
advantage of a strategic decision over competitors	0.08	0.07	0.06	0.08	0.08	0.07	0.07
adequacy and adequacy of human resources	0.11	0.11	0.11	0.09	0.10	0.11	0.11
compatibility with economic factors	0.09	0.07	0.10	0.10	0.11	0.09	0.09
compatibility with social factors	0.07	0.07	0.09	0.06	0.06	0.08	0.07
compatibility with technological factors	0.10	0.12	0.10	0.08	0.09	0.10	0.10
compatibility with ecological factors	0.06	0.05	0.05	0.08	0.07	0.08	0.07
adequacy of financial resources	0.10	0.10	0.11	0.12	0.10	0.12	0.11
appropriateness of the payback period	0.09	0.09	0.08	0.09	0.07	0.08	0.08
value to the consumer	0.07	0.08	0.07	0.07	0.08	0.06	0.07
compliance of the strategic alternative with the organizational culture.	0.05	0.05	0.06	0.05	0.05	0.05	0.05

Table 3

Evaluation of strategic distribution alternatives in the context of institutional dimension

Types of logistics process management solutions	Alternatives to logistics process activities	SAW (T)
Customers selection	Own cargo warehousing	0.0819
	Cargo warehousing for one customer	0.0829
	Cargo warehousing for more than one customer	0.0830
	Mixed	0.0824
Selection of stored cargo by expiration date	Long validity	0.0838
	Short validity	0.0835
	Mixed	0.0821
Selection of stored cargo according to special requirements	Temperature regulation	0.0830
	Reservoir	0.0828
	Standard	0.0832
Provision of additional storage services	Packing	0.0832
	Sorting	0.0832
	Cutting	0.0831

Conclusions

1. Food distribution logistics management in the context of institutional dimension is one of the core activities of a company to increase its competitiveness, but main decisions must be done in company's strategic level. Improper food distribution 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 quality, increasing attention is paid to the sustainable development integrity in company activities.
2. In order to create a food distribution system management model in the context of the institutional dimension, a systematized distribution system model and evaluation system

are presented. However, to perform a proper assessment of alternatives, it is appropriate to apply a multi-criteria assessment and identify the main criteria. Distribution logistics chain management sustainability is most clearly seen and analyzed by using SAW method.

3. A practical examination of the developed model and the application of the evaluation system in the food distribution company revealed that the evaluation system is appropriate and helps to identify the most appropriate strategic decisions. Based on the developed evaluation methodology, the company can evaluate various strategic decisions in the context of sustainability according to the institutional dimension. Results help to identify and choose most suitable alternatives which can increase sustainability level of the company.

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PREVALENCE OF FELINE CORONAVIRUS IN CATS OF AN ANIMAL SHELTER IN LATVIA

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Abstract

Feline coronavirus (FCoV) is ubiquitous in the domestic cat (*Felis catus*) population. The aim of this study was to determine the prevalence and potential predisposing factors of FCoV in cats of an animal shelter in Latvia and to compare the prevalence between cats in the quarantine area and resident cats in the adoption area. Oropharyngeal and faecal swabs and blood samples were collected from 40 domestic shorthair cats from an animal shelter in Jelgava, Latvia. Swabs were analyzed for FCoV RNA by reverse transcriptase-polymerase chain reaction (RT-PCR). Blood serum samples were tested for FCoV specific antibodies by indirect enzyme-linked immunosorbent assay (ELISA). FCoV RT-PCR positivity in oropharyngeal and rectal swabs was 7.5% (3/40) and 72.5% (29/40), respectively. Additionally, FCoV seroprevalence was 67.5% (27/40). The proportion of cats shedding FCoV within the adoption (72.7%) and quarantine (72.2%) areas was similar ($p = 0.55$). The prevalence of FCoV faecal shedding in young cats was significantly higher ($p < 0.05$) than in adult cats. Sex had no significant effect on FCoV RT-PCR positivity. Further studies on larger cat population including different population types are needed to determine the overall prevalence and epidemiological patterns of FCoV infection in Latvia.

Key words: coronavirus (CoV), feline infectious peritonitis (FIP), feline coronavirus (FCoV), cats, animal shelter, RT-PCR.

Introduction

Coronaviruses (CoVs) are enveloped viruses with an exceptionally large (27–32 kb) positive-stranded RNA genome. They are divided into four different genera: alpha, beta, gamma, and delta coronaviruses based on their genomic characteristics (Le Poder, 2011). CoVs are a diverse group of viruses that are common in nearly every species of mammals and birds (Pedersen, 2014). Because of their large RNA genome, CoVs have moderate to high mutation and recombination rate, and this facilitates successful cross-species transmission (Su *et al.*, 2016). This paper focuses on feline coronavirus (FCoV) which is the most common pathogen identified in the faeces of cats (*Felis catus*) and is the causative agent of one of the most researched infectious diseases of cats: feline infectious peritonitis (FIP) (Pedersen, 2014). Feline coronaviruses (FCoVs) belong to the genus *Alphacoronavirus* and are grouped into two biotypes: low virulent FCoV which is primarily a pathogen of the gastrointestinal tract and highly virulent FCoV which has arisen from spontaneous mutations in the low virulent FCoV. Highly virulent FCoV has gained tropism for monocytes/macrophages enabling systemic spread (O'Brien *et al.*, 2018) and a subset of infections (7–14%) with highly virulent FCoV result in almost uniformly fatal FIP (Addie *et al.*, 2020). Although highly virulent FCoV is responsible for the development of FIP, low virulent FCoV is the real culprit behind the maintenance of FCoV in multi-cat households, meaning that persistently infected and shedding cats play a key role in the

epidemiology of FIP (Kipar & Meli, 2014). Once a cat has been infected with low virulent FCoV, there is a potential for FIP to develop. Some strains are more prone to cause FIP than others. FCoV is endemic in the domestic cat population worldwide, especially within multi-cat households and catteries with seropositivity rates approaching 90% (Tekes & Thiel, 2016). There is currently no approved treatment for FIP and no effective vaccine against FCoV (O'Brien *et al.*, 2018); therefore, detection and removal of FCoV shedders, as well as good hygiene practices are the essential tools for preventing transmission of FCoV. The importance of FCoV is not limited to the cat population only, as cats live in close contact with humans and are the most frequently kept species of companion animals (106 million) in Europe (FEDIAF, 2019). Knowing the high densities of domestic cats, the high prevalence of FCoV and the fact that CoVs are continuously adapting themselves to new hosts, FCoV cannot be neglected in terms of the One Health concept. There is considerable knowledge on the prevalence of FCoV and associated risk factors in many countries, but at the present time information on the current burden of FCoV in shelters in Latvia has not been examined; however, epidemiological results can differ among geographic locations (Worthing *et al.*, 2012). The aim of the present study was to estimate the prevalence and potential predisposing factors of FCoV in cats of an animal shelter in Latvia and to compare the prevalence between cats in the quarantine area and resident cats in the adoption area.

Materials and Methods

Study population

Samples from 40 domestic shorthair cats (22 male and 18 female) were collected from an animal shelter in Jelgava, Latvia, between September 2020 and January 2021. Examined cats were housed in a quarantine zone for incoming cats and in an area designated for resident cats. Age was provided by the owners who surrendered their cats or estimated by shelter staff in stray cats. The youngest cat tested was 2 month old, but the oldest was 12 years old; they were categorized as juvenile (<1 year) and adults (≥ 1 year). The clinical condition of all cats enrolled in this study was not an excluding factor. The study was approved by the Committee for the Protection of Animals Used for Scientific Purposes of the Food and Veterinary Service of the Republic of Latvia (certificate of approval No 119).

Sample collection

From each cat two polyester-tipped swabs (oropharyngeal and rectal) and one blood sample were collected. No anesthetic when collecting the samples was used, only proper handling, and a minimum of physical restraint. For swab collection, transport, and maintenance UTM® paired with COPAN FLOQ Swabs® were used. Commercial UTM™ conical tubes were filled with 3 mL UTM™ medium. Half of the viral transport medium was poured into sterile 1.5 mL Eppendorf Tubes® before taking the swabs. For the collection of oropharyngeal specimen, the minitip size swab was inserted into the caudal oropharynx and tonsillar areas. The sample was collected by rubbing the polyester-tipped shaft against the caudal oropharynx while trying to avoid contact with the tongue, teeth, and gums. Then the swab was inserted into the UTM™ tube until the breakpoint was level with the tube opening and the swab shaft was broken off at the breaking point. The second regular size swab was inserted 1.0–1.5 cm into the rectum. The sample was collected by gently rolling the swab against the rectal mucosa, then the swab was inserted in the pre-filled Eppendorf Tube® and the shaft was cut leaving a tip of the swab into viral transport medium. For blood collection vacuum tube with clot activator and 23-gauge butterfly catheter were used. The cephalic vein was occluded with a tourniquet, the venipuncture site was clipped and cleaned with 70% isopropyl alcohol pad. Subsequently, the butterfly catheter was inserted intravenously. From each cat about 0.7 to 1.5 mL of peripheral blood was obtained. Then the tourniquet was released, the catheter was withdrawn and pressure to the puncture site was applied.

Serological testing

All blood serum samples were tested for the presence of specific antibodies to FCoV by an indirect enzyme-linked immunosorbent assay (ELISA) using a commercial INGEZIM CORONA FELINO indirect

ELISA kit (Ingenasa, Spain). The procedure of the test was carried out according to the manufacturer's instructions. Briefly, a commercial plate is already coated with the specific FCoV antigen. For the reaction 200 μ L of serum dilution 1/200 were added to the plate and incubated. If the samples contained specific antibodies to FCoV, they bound to the antigen. The plate was washed and the specific peroxidase conjugate was added. The second washing of the plate followed and the substrate was added to the wells. The Multiskan FC® spectrophotometer (Life Technologies, Singapore) was used to measure the optical density (OD) of the colorimetric reaction. The cut-off value was determined according to the user manual of the kit. The samples with an OD value higher than the cut-off were considered positive and having specific antibodies to FCoV. The samples with an OD value lower than the cut-off were considered as negative for the presence of specific antibodies to FCoV.

Detection of FCoV by reverse transcriptase-polymerase chain reaction (RT-PCR)

Viral RNA was extracted from 200 μ L of sample using the IndiSpinPathogen kit (INDICAL, Leipzig, Germany). The RNA was eluted in 100 μ L of elution buffer and stored at -80 °C. CoV screening was performed by a pan-coronavirus one-step RT-PCR followed by sequencing of the amplified product (440 bp) to confirm CoV identification. PCR was performed by adding 5 μ L of extracted RNA to 20 μ L of the SuperScript™ III One-Step RT-PCR System with Platinum™ Taq DNA polymerase kit (Invitrogen, Carlsbad, USA) reaction mixture containing 0.5 μ M of each primer (RdRP2-F GGTTGGGACTATCCTAAGTGTGA and RdRP2-R CCATCATCAGATAGAATCATCATA) (Poon *et al.*, 2005). RT-PCR was carried out at 50 °C for 30 min, followed by the activation of the DNA polymerase at 95 °C for 2 min, and by 40 cycles in three steps: 95 °C for 30 s, 50 °C for 30 s, and 68 °C for 1 min. An additional extension for 10 min at 68 °C was added at the end of the run. The RdRp PCR products were enzymatically purified using ExoI and FastAP (Life Technologies, Fermentas, Lithuania) and were subjected to nucleotide sequence analysis.

Statistical methods

Descriptive statistics for the age of the cat, sex, area in the shelter and FCoV status in all sample types was calculated using Student's t-tests for unpaired samples. P-values of less than 0.05 were considered statistically significant. Additionally, the Pearson correlation coefficient was calculated for RT-PCR and ELISA results.

Results and Discussion

A total of 40 cats from a single shelter were included in the study, of those 22 (55%) resided in the

Table 1

RT-PCR and indirect ELISA results according to animal sex and age

Factor	Category	RT-PCR		Indirect ELISA
		rectal swabs (FCoV RNA) (No. Positive/Total samples)	oropharyngeal swabs (FCoV RNA) (No. Positive/Total samples)	serum samples (FCoV specific antibodies) (No. Positive/Total samples)
Sex	Male	16/22	1/22	12/22
	Female	13/18	2/18	15/18
Age	<1 year	13/14	0/14	9/14
	≥1 year	16/26	3/26	18/26

adoption area and 18 (45%) were kept in quarantine. The overall prevalence of previous or ongoing FCoV infection was 82.5% (33/40). Out of the 40 cats, 29 cats (73%) were shedding FCoV, but 27 cats (68%) had anti-FCoV antibodies. There was no significant difference ($p = 0.55$) between the proportion of cats shedding FCoV within the adoption (72.7%) and quarantine (72.2%) areas. These results demonstrate that compartmentalization of the particular shelter into individual sections did not reduce transmission of FCoV and different prevention strategies for FCoV infection should be applied. Shedding cats are responsible for the persistent presence of FCoV in the domestic cat population (Felten *et al.*, 2020) therefore, in order to avoid continual reinfection, shedders must be isolated. In previous studies estimated FCoV seroprevalence in multicat environment was highly variable, ranging from 25.6% in the United Kingdom (Cave *et al.*, 2004) to 82% in Italy (Pratelli, 2008) depending on various factors such as population density, husbandry practices, time spent in the shelter before sampling, age, breed, and health status (Cave *et al.*, 2004). Faecal shedding, as determined by RT-PCR from rectal swabs, in previous studies with mixed-breed cats in multicat environment was similar to our results. The overall prevalence of FCoV infection in the cat population in Malaysia and Germany was 70% (Sharif *et al.*, 2009) and 76.5% (Klein-Richers *et al.*, 2020), respectively.

The whole study population consisted of 22 (55%) neutered males and 18 (45%) neutered females. We found no significant correlation between FCoV-positivity and the sex of the cats ($p = 0.55$). FCoV prevalence in male cats (72.7%) was almost the same as in female cats (72.2%). Among the 29 FCoV-positive cats, 13 (45%) were less than 1 year old and 16 (55%) were older than 1 year. Prevalence of FCoV fecal shedding in young cats (92.9%) was significantly higher ($p < 0.05$) than in adult cats (61.5%) (Table 1). We observed that young age was the only significant factor associated with FCoV shedding (RT-PCR positivity in rectal swabs). Our findings support

previous studies that found a significant correlation between FCoV-positivity and the young age but no significant association between FCoV-positivity and sex of the cats (Klein-Richers *et al.*, 2020; Pedersen, Allen, & Lyons, 2008).

FCoV RNA was detected in 3/40 (7.5%) oropharyngeal swabs and in 29/40 (72.5%) rectal swabs but FCoV specific antibodies in 27/40 (67.5%) blood serum samples. The proportion of positive rectal swabs potentially could be even higher because only a single rectal swab from each cat was analyzed and according to previous studies, 70–80% of infected cats are intermittent shedders (Klein-Richers *et al.*, 2020). Overall, 85% (23/27) of FCoV specific antibody-positive cats shed FCoV in their faeces. There was a moderate positive correlation between the presence of FCoV specific antibodies and FCoV shedding in feces ($r = 0.41$, $p < 0.01$). This observation is in accordance with previous reports which showed that cats with antibodies were more likely to be the virus shedders than non-shedders (Felten *et al.*, 2020; Pedersen, Allen, & Lyons, 2008).

However, the prevalence of FCoV in shelter cats cannot be extrapolated to the overall cat population of Latvia. Further studies on larger cat population including different population types are needed to determine the overall prevalence and epidemiological patterns of FCoV in Latvia.

Conclusions

1. In this study, the prevalence of previous or ongoing FCoV infection in cats of an animal shelter in Latvia was 82.5%; additionally, young age was a predisposing factor for FCoV infection.
2. The difference between cats shedding FCoV within the adoption (72.7%) and quarantine (72.2%) areas was not significant ($p = 0.55$), thereby new prevention strategies should be applied to reduce FCoV infection and control FIP outbreaks since compartmentalization did not decrease the spread of FCoV.

3. A follow-up study should be performed to investigate the development of FIP in conjunction with RNA sequencing of FCoV to identify specific mutations in the FCoV genome.

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INTEGRATE HEALTH CARE SYSTEM PERFORMANCE ASSESSMENT FOR VALUE-BASED HEALTH CARE IMPLEMENTATION IN LATVIA





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Abstract

Every year, efforts are applied worldwide, particularly in the European Union, to improve health care systems by increasing the added value of resources already available for health care financing by increasing the performance of health care systems. According to experts of the World Health Organisation (WHO) and the Organisation for Economic Cooperation and Development (OECD), 20–40% of the resources are used for complications that could be avoided, for unnecessary treatment or administrative inefficiency. Therefore, a new initiative to improve health performance – the value-based health care concept (VBHC) is becoming increasingly popular in the world, and particularly in Europe.

This scientific article aims to explore the possibilities of applying VBHC in Latvia and the interaction between various management tools in the field of health care. Application of the VBHC concept in Latvia is offered for discussion, where the outcome of the corresponding measure would be identified for each health service provider as part of a one-patient (care) pathway involving several independent health service providers. Based on the Health Care System Performance Assessment (HSPA), clinical (patient) pathways and indicators, to initiate an integrated VBHC model in four priority areas: circulatory system diseases, oncology, mental health, maternal and child health.

Meta-analysis of the research is based on the use of qualitative data sources – the existing data sources from policies implemented by the Ministry of Health in Latvia and examples of the introduction of VBHC initiatives worldwide summarised by the VBHC Center Europe. The deductive research is based on the Value-Based Healthcare concept introduced by Porter and Teisberg (2007).

Key words: Health System Performance Assessment; VBHC; Health policy, Patient pathway; Scorecards; Outcome Measures.

Introduction

Every year, efforts are applied worldwide, particularly in the European Union, to improve health care systems by increasing the added value of resources already available for health care financing, by increasing the performance of health care systems. This issue is relevant for Latvia, where financing allocated to the health sector from the general government-subsidised sectors is one of the lowest among the OECD countries (4.03% of GDP in 2018, 3.53% in 2017, 3.73% in 2016, 3.75% in 2015, 3.80% in 2014) (Pētersone, Ketners, & Eriņš, 2019; OECD, 2020), due to the need to ensure the efficient functioning of the system within the limited resources.

According to experts of the World Health Organisation (WHO) and the Organisation for Economic Cooperation and Development (OECD), 20–40% of the resources are used for complications that could be avoided, for unnecessary treatment or administrative inefficiency (OECD, 2017). There of a new initiative to improve health performance – the value-based health care concept (VBHC) is becoming increasingly popular in the world, and particularly in Europe. Several bright examples of using the value-based health care concept can be mentioned. *Martini Klinik* (Hamburg, Germany) for the treatment of prostate cancer (Porter, Deerberg – Wittram, & Feeley, 2019). *The Karolinska University Hospital*

(Stockholm, Sweden) reorganised its structure from the classical departments into 270 integrated practice units (IPUs). Netherlands – outcomes of cardiac interventions are collected in a nationwide initiative (Meetbaar Beter). *Diabeter* (Netherlands) Dutch-certified clinic network that specialises in providing comprehensive and individualised care for children and young adults with type 1 diabetes (Deerberg-Witramand & Lütke, 2016). *Boston Children's Hospital* (BCH) (USA) aimed to be a worldwide leader in improving children's health through the provision of high-quality care, cutting-edge research, teaching and local community outreach (Kaplan, Witkowski, & Hohman, 2012). French ophthalmic centres – *Institut Ophtalmologique Sourdille Atlantique*, *University Hospital* in Nantes and *Chénieux Ophtalmologie at Polyclinique de Limoges* – have recently adopted the standard set for cataract surgery developed by the International Consortium for Health Outcomes Measurement (ICHOM).

Latvian scientists, policymakers and practitioners have also expressed interest in value-based health care and all benefits that such an initiative can provide. Thus, Barzdiņš *et al.* (2019), having analysed the treatment of myocardial infarction (AMI) in Latvia by using administrative data, have concluded that the results obtained from the research confirm that the quality and results of AMI treatment in entire Latvia

Table 1

Non-financial Targets

Sub-target	Performance indicators	Dimensions
Service availability	Ratio of number of practitioners and nurses	input
	Total number of patients in hospital/outpatient	output
	Number of beds in a medical institution	input
	Average waiting time to receive a consultation from an outpatient specialist	process
Efficiency of services	Average duration of treatment in a hospital	process
	Average loading of beds in a 24 h in-patient clinic	output
	Average load of CT and magnetic resonance equipment	output
	Share of functional specialists from all employees	input
	Proportion of working medical practitioners in the age group 25–40 from the total number of medical practitioners	input
Quality of services	Patient mortality rate, number and proportion	outcome
	Number of complications	outcome
	Proportion of medical practitioners working overtime during the period considered	input
	Volume of patients released home who were re-hospitalised on the same or next day	outcome
Knowledge transfer	Independent research activities	output
	Students education and professional development process of practitioners and medical support persons	output

(Barzdins *et al.*, 2019) should be improved by taking concrete measures. In the context of structural reforms, a number of projects financed by the European Structural Fund have been implemented – Health Care System Performance Assessment (Baltāne, 2018), “Development and Introduction of Guidelines for the Health Care Networks Development and Quality Assurance Systems within the Priority Health Care Areas”, “Establishment of a Public Monitoring System for the Quality and Efficiency of Health Care”.

However, the assessment of different aspects of health care sector alone does not create a mechanism for improving the functioning of all parties involved in the health system, particularly at the level of clinical university hospitals.

This scientific article aims to explore the possibilities of applying VBHC in Latvia and the interaction between various management tools in the field of health care.

The main idea of the research is to arise discussions on VBHC valuables among scientists, policy makers, non-governmental organisations, doctors’ associations and health services providers in Latvia regarding who should step with an initiative and how the VBHC interpretation in Latvia should look like conceptually.

Porter and Teisberg (2007) introduced the value-based healthcare concept as a reform strategy for health care systems, which is market-based but conducted by

doctors. “The right kind of competition—competition to improve results—will drive dramatic improvement” (Porter & Teisberg, 2007; Porter & Lee, 2013; Porter, 2010). Still, Vainieri *et al.* (2020) took a holistic view regarding the value-based concept, which means a less individually-focused approach (patient-centred), as initially claimed by Porter (2010), and a more socially inclusive perspective that considers, for instance, equity aspects. When discussing the integration of VBHC into the Latvian health care system, a holistic approach of the concept should be discussed, focusing on shifting the focus of attention from the volume of services (output) to the value or results achieved (outcome) within all levels of health service providers, emphasising that the value is not measured according to the health care process used (process). Still, measuring and improving is an important tactic, but it cannot replace the determining of results and costs. Table 1 summarises non-financial targets, according to which state companies of the Latvian health care sector assess their operation (Cross-Sectoral Coordination Centre, 2018).

As we see from Table 1, regarding non-financial targets, the volume of services is mostly assessed at state companies in Latvia, and only in certain cases the service value. When evaluating activities of hospitals, Table 1 reflects a number of performance aspects, but these indicators do not reflect personal value, technical value, allocative value and public value in the VBHC

context (EC, 2019), whereas strategic financial objectives are in compliance with the principles of good management of public companies.

Materials and Methods

As the research method, meta-analysis based on the use of qualitative data has been chosen – the existing data sources from policies implemented by the Ministry of Health in Latvia and examples of the introduction of VBHC initiatives worldwide summarised by the VBHC Center Europe. The deductive research is based on the Value-Based Healthcare concept introduced by Porter and Teisberg (2007).

Based on qualitative data, conclusions have been reached and a pragmatic approach has been proposed to systematically assess the performed activities, the application of specific policies and the implementation strategy for assessing and developing the performance of the health care system in Latvia, combined in an integrated initiative to implement the value-based health care concept.

“Assessment of the performance of health care systems is a valuable factual material that helps in policy-making. It can also be seen by healthcare providers as a strategic framework for monitoring progress and evaluating best practices by linking health indicators to the health system strategy and functions” (EC, 2020). Health Systems Performance Assessment (HSPA) has established a set of indicators that describe the following health care dimensions:

- resources (input) (finances, human resources and other provision);
- process (process) (e.g., accessibility, quality, safety);
- short-term result (outcome) (e.g., received care, mortality);
- long-term result (outcome) (e.g., survival).

Noto *et al.* (2019) built upon the Donabedian conceptual model, the HSPA framework for Latvia has been characterised by four main domains, which are Structures, Processes and Outcomes, organised in multiple key dimensions, namely, Financial Resources, Human Resources and Equipment (Structures), Efficiency, Quality, Safety, Prevention, Demand Management, Equity, Accessibility and Health Status (Processes and Outcomes). Due to the lack of available data, the Patient Experience domain has not been populated by indicators yet. HSPA have been identified within the domains of Processes and Outcomes. At present, the framework consists of the overall number of 191 indicators classified in the domains, dimensions and pathways as portrayed (Noto *et al.*, 2019), i.e. 23 structure indicators, 80 process indicators and 88 outcome indicators.

HSPA provides benchmarking of indicators in Latvia. Depending on the indicator, the assessment

is performed at the international, regional, local and health service providers’ level. The indicators (performance) generally focus on four priority areas: circulatory system diseases, oncology, mental health, maternal and child health. The framework foresees the benchmarking of indicators (performance) (Lepiksone, 2019), which have an informative nature at the level of health service providers.

In addition, in these four priority areas of the project co-financed by the European Social Fund, to implement “the development and implementation of guidelines for the development of health care networks and quality assurance systems within the framework of priority health care areas”, clinical guidelines and the relevant clinical algorithms, clinical (patient) pathways and indicators for the four priority areas have been identified. In order to improve the quality of the patient health care, 115 clinical algorithms and 92 clinical patient pathways will be developed over the coming years (SPKC, 2010).

A management mechanism is missing where each independent health service provider is responsible for its service and, at the same time, would be interested in achieving the overall outcome. All health systems face similar challenges. The European Union Member States are introducing Value-Based Health Care (VBHC) to improve individual health conditions.

The European Institute of Innovation and Technology (EIT), in its “Handbook for Pioneers – Implementing Value-Based Health Care in Europe”, has developed the VBHC implementation matrix. The implementation matrix is based on six dimensions and nine matrix elements: Condition, Partnering (External Collaboration and Internal Forces), Comparing, Rewarding (Investments and Incentives), Improving, Recording (Data platform and Scorecard).

Scorecard defines processes, costs and outcome indicators while applying case-mix adjustment. The scorecard aims to measure the value of care for a specific condition, by incorporating a minimal set of process, outcome and cost indicators. Process measures how care was delivered. Outcomes measure the impact on patient health status. Costs measure the money spent to achieve these outcomes. Combined, these three metrics track changes to detect variation over improvement cycles (EIT Health, 2010).

According to their structure, the clinical (patient) pathways and corresponding indicators, which are developed in Latvia in the context of the reforms, correspond to the scorecard aims defined by “Handbook for Pioneers – Implementing Value-Based Health Care in Europe”.

Results and Discussion

Conceptually, VBHC makes it possible to function at the level of the health care system (Pētersone,

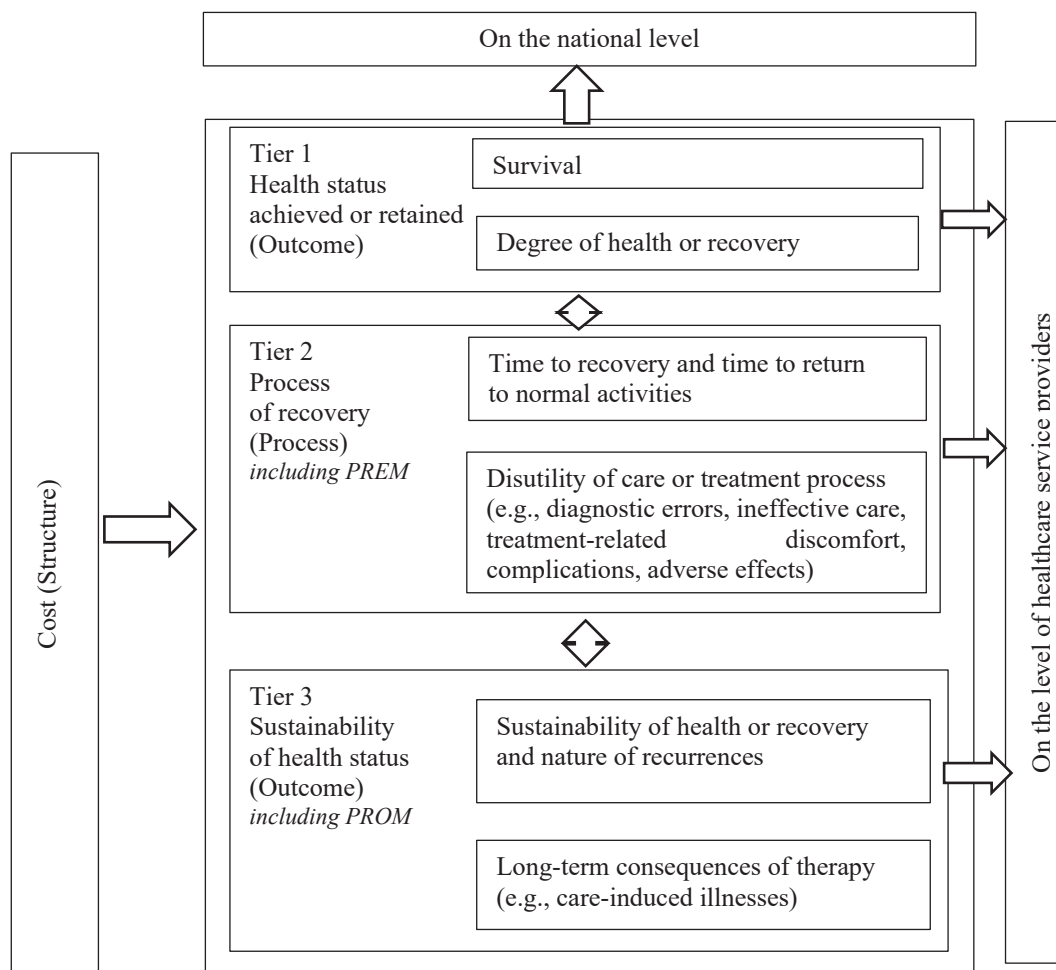


Figure 1. The Outcome Measures Hierarchy (developed by the authors based on Porter 2010).

Ketners, & Erins, 2020), whereas in Europe it is mainly used at the level of health care providers (VBHC Europe, 2020). Taking into account the Latvian health care financing model, population and the special features of the health services management systems (Pētersons *et al.*, 2019), the authors offer the discussion on the application of the VBHC concept in Latvia at the level of the health care system, where, within the framework of one patient's (care) pathway, with involvement of several independent health service providers, the outcome of the corresponding measures would be identified for each health service provider. Based on existing HSPA, clinical (patient) pathways and indicators should initiate an integrated VBHC model in four priority areas: circulatory system diseases, oncology, mental health, maternal and child health. It is necessary to complement the VBHC model with missing indicators to better reflect the VBHC model in Latvia. In addition, it is proposed to create a cascade of indicators based on the Outcome Measures Hierarchy by Porter (2010) (Figure 1).

In line with Porter (2010), the VBHC Outcome Measures Hierarchy can be recommended for Latvian

circumstances, which provides three assessment levels for the system. Tier 1 is the health status that is achieved or retained (Survival and Degree of health or recovery). Tier 2 outcomes are related to the recovery process (Time to recovery and time to return to normal activities and Disutility of care or treatment process (e.g., diagnostic errors, ineffective care, treatment-related discomfort, complications, adverse effects)). Next Tier 3 is the sustainability of health status, which can be divided into two sub-levels: Sustainability of health or recovery and nature of recurrences and Long-term consequences of therapy (e.g., care-induced illnesses).

The cascading of indicators is essential for the inclusion of health indicators identified in the national planning documents to the strategic planning documents of health service providers, as individual indicators can be traceable at regional and municipal level. The strategy and the strategic action plan of the health service provider should be based on VBHC indicators (outcome and process) when defining objectives, tasks, performance results and indicators and numerical values. Currently, a group of analytical

indicators for the performance measurement system is focused on the performance analysis and improvement of the organisational volume indicators. The traceability of performance and interconnectedness of various organisational units of the health service provider would help in management of the operational process.

VBHC offer a complex mechanism of management, e.g. the VBHC Implementation Matrix, where one of the elements is Scorecard. HSPA and the outcome, process and structure indicators of the clinical (patient) pathway conforms in their structure to the Porter's Outcome Measures Hierarchy.

In the strategic purchasing context, the outcome and process indicators of the health service providers can be one of the Criteria for Section of a Health Care Facility and Signing of a Mid-Term Contract on Health Service Provision (Pētersone *et al.*, 2020; Van Veghel *et al.*, 2018).

The health service providers are starting to collect parameters for Patient Reported Experience Measures (PREMs) (Slawomirski *et al.*, 2018) increasingly more often. Latvian Clinical University hospitals have started collecting data from PREMs, as well as have been involved in the project financed by the European Structural Fund for the development and implementation of the PREMs system. Although PREMs are not classified as a health outcome measure, rather as a process measure, such information is an important source in improving the management of hospital processes that will allow to improve care in line with expectations of patients.

Patient reported outcome measures (PROMs) are longitudinally collected to measure effectiveness within clinical trials or for improving individual patients' health status by means of his or her reported functional, psychological and social outcomes (Van Der Wees *et al.*, 2014). PROMs data are not collected in Latvia; however, it is an innovative policy also in Europe (Pennucci, Rosis, & Passino, 2020). The PaRIS survey fills a critical information gap in primary care, focusing on PREMs and PROMs. The Patient-reported Indicator Surveys (PaRIS) initiative of the Organisation for Economic Cooperation and Development (OECD) is currently in its design phase (OECD, 2020).

The most complicated and contentious issue is and remains cost accounting and accounting per one patient. Within the framework of the values, the corresponding total costs are used in the single patient's full cycle of care. Costs per patient are a hard-to-measure indicator for a number of reasons, mainly because hospital cost accounting systems

are departments, not patients, and they are intended for settlements for transactions payable under pay-per-service contracts. Large health service providers who want to introduce VBHC to justify a cost per patient are recommended to use the Time-Driven Activity-Based Costing (TDABC). (Beck da Silva Etges, Polanczyk, & Urman, 2020; Cidav *et al.*, 2020) TDABC, just as the VBHC initiative is based on scorecard identification (Keel *et al.*, 2017).

Conclusions

By showing their own initiative, leading health service providers in Europe are increasingly introducing a value-based healthcare concept (VBHC) into their work organisation.

Conceptually, VBHC provides for the possibility of functioning at the healthcare system level; however, it is mainly used at the level of healthcare providers in Europe.

Just setting of the indicators benchmarks in Latvia does not create a mechanism to improve the functioning of the health system, particularly at the level of Clinical University hospitals. A management mechanism is missing where each independent health service provider is responsible for its service and, at the same time, would be interested in achieving the overall outcome.

The cascading of indicators is essential for the inclusion of health indicators identified in the national planning documents into the strategic planning documents of health service providers, as individual indicators can be traceable at the regional and municipal level.

Large health service providers who want to introduce VBHC to justify a cost per patient are recommended to use the Time-Driven Activity-Based Costing (TDABC).

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THE AMBIGUITY OF COVID-19 EFFECT ON THE LATVIAN FISHERY SECTOR

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Abstract

The dramatic change in various spheres of daily life caused by the COVID-19 virus epidemic has had many ambiguous effects on the Latvian fisheries sector.

As part of a national research program project reCOVery-LV to study the virus's effect on the supply chain, LLU researchers concluded that Latvian fish processing demonstrates a multidirectional effect. The interpretation of statistics and the interviews conducted confirmed the hypothesis that the virus has had negative and positive effects within one sector of the economy. This industry heterogeneity places high demands on support criteria, making them more targeted for successful risk management. *The research aims* to analyze the fishery sector and identify the COVID-19 pandemic effect on Latvia's fish sector. As part of the study, all stages of the fish food chain were studied, risks were identified, their relative relevance was determined, and measures were proposed to neutralize these risks. This article summarizes the results of the study, prioritizes the implementation of countermeasures that reduce risks and are recommended by the results of the risk assessment, and complement the results of the study, identifies measures aimed at the long-term and sustainable development of the industry, based on the lessons of the COVID-19 pandemic.

Key words: COVID-19 effect, risk management, institutional measures, policy implications, fishery sector.

Introduction

The COVID-19 pandemic in Latvia has imposed several restrictions on all food system stages, including the fish food supply chain. The industry and consumption of fish products in Latvia are embedded in the global flows of fish raw materials and are subject to many risks affecting international supply and demand. Besides, the fishing industry is characterized by various fish raw materials, with different origins – both from the European Union (EU) and surrounding countries and from far abroad.

The fish processing sector differs from other food industry sectors in various options for all food system stages. In particular, fish processing, depending on local and imported raw materials, meets local and export buyers' needs. As a result, many identified risks are characteristic only for some and generally do not apply to other enterprises in the sector. It makes it impossible to generalize about "self-sufficiency in fish in general". Fishers catch some types of fish, processors process others for a significant part, working mainly for export, and consumers consume the third, mostly imported.

The research aims to analyze the fishery sector and identify the COVID-19 pandemic effect on Latvia's fish sector. The following specific research tasks were set to achieve the aim: 1) to analyze the fishery sector in Latvia; 2) to identify the impact of the COVID-19 pandemic on the fish sector in Latvia.

Materials and Methods

As part of the study, interviews were conducted with fishers, fish breeders, and processors of different types of fish. The current state and impact of the COVID-19 pandemic on all stages of the food chain were studied. Targeted conclusions were made based

on import-export statistics in the type of processing, type of fish, and relevant markets.

Theoretical Background

Building a sustainable food system is one of the EU Green Deal programs' objectives (Krämer, 2020). COVID-19 pandemic poses risks and affects the sustainability of all links in the food chain (Cullen, 2020), highlighting those bottlenecks in food chains that might have gone unnoticed in the absence of a crisis but demanded immediate solutions to avoid system collapse (Shay & Murphy, 2020; Qin, 2020).

There is broad consensus over the definition of "risk" among leading national and international standards and guidelines, as well as professional bodies (Chapman, 1997; Project Management Institute, 2000). A typical two-dimensional definition of risk in the realm of management is "An uncertain event or condition that, if it occurs, has a positive or a negative impact on a project objective" (Project Management Institute, 2000). The impact of risk is a tangible value of downside "in the event of a risk." The likelihood is clear that this is a subjective perception of the interviewees, which cannot be calculated if only due to the current situation's uniqueness (Hillson & Hulett, 2004). Both in the study and this article, risks are ranked by combining these factors for the possibility of prioritization.

Many authors and international organizations state the pandemic consequences and suggest possible institutional solutions to emerging crises (FAO, 2020b), (OECD, 2020). Besides, many works are devoted to the situation and possible political decisions in the fishery sector (FAO, 2020a; Manlosa, Hornidge, & Schlüter, 2021; Love *et al.*, 2021). Specific risks and possible solutions are grouped

according to the food chain stages and are described in the following parts.

Results and Discussion

Analysis of the Fishery Sector in Latvia

Consumption. Fish is a traditional food for Latvia due to its geography and history. Latvia residents consume 24.9 kg of fish per person per year, which is higher than the EU average (24.5 kg) and significantly higher than in neighboring Lithuania and Estonia (15.6 kg and 16.3 kg, respectively). Regular consumers, namely those who eat fishery and aquaculture products at least once a month, mainly belong to 40–54 and over 55. Young people (15–24) are less inclined to consume fish in Latvia and at the EU level. In this category, regular consumers cover 64% of the total, which is slightly lower than at the EU level (67%). Latvians consume mostly fresh and smoked products; loose fish (66%) is slightly less frequently consumed than at the EU level (68%) (CSB, 2019).

Latvians spend on fish on average 4.7 times less than on meat and meat products, while on average in the EU, this figure is 4.4 times.

The full range of activities required to deliver fish and fishery products from production to the final consumer are complex. Each link in the chain is

susceptible to being disrupted or stopped by impacts arising from COVID-19. The desired result, human consumption of fish and fishery products, can only be achieved by protecting the producer-buyer-seller links and each stage of the supply chain (FAO, 2020a).

Based on the risks associated with a change in consumer habits, a shortage of products in the store, and a drop in consumers’ ability to pay, possible measures were developed to prevent and combat the consequences. Only the decline in the population’s ability to pay fell into the category of Probable and Having a significant impact. One possible institutional measure is to reduce the VAT rate on food and government support for consumption - food receipts for specific categories of citizens. Besides, in times of crisis and a possible extension of food chains, products with extended shelf life are in high demand. Today, manufacturers cannot offer suitable products other than canned food, which causes excitement and excessive demand, which must be processed (by increasing production, storage capacity).

Production. The fishery industry in Latvia is characterized by using various raw materials (Figure 2).

Small pelagics make up the vast majority of fish caught in Latvia (92%). Small pelagics are composed of both sprat (*sprattus sprattus balticus*) and Baltic

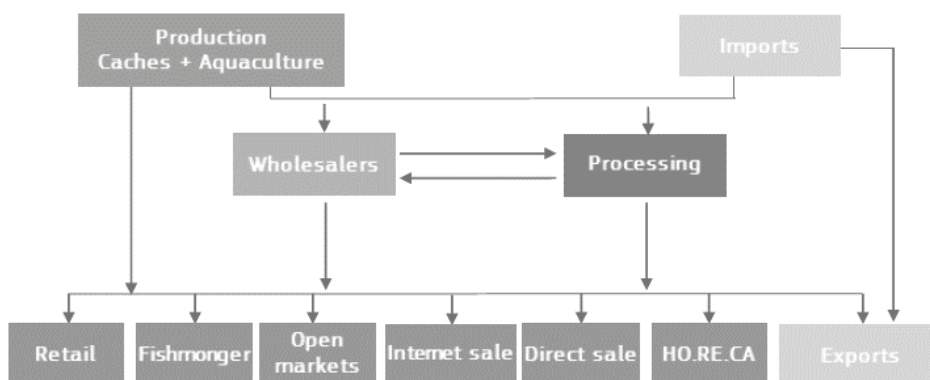


Figure 1. The Supply Chain of Fisheries and Aquaculture Products in Latvia.

Source: Authors’ construction.

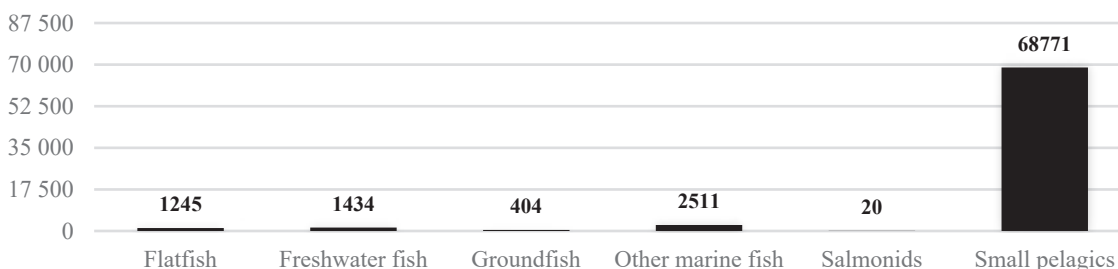


Figure 2. Raw Materials Landed in Latvia in 2018 (thousand tons).

Source: Zemkopības ministrija, 2019.

herring (*Clupea haeringus*). In 2019, 601.9 tons of fish were grown in Latvia (aquaculture – Carp, Trout, Sturgeon), which is less than 1% of the wild fish caught.

Processing. Fish processing in Latvia in 2019 consisted of 130 companies (State Veterinary Service Register, Business Register) with a total turnover in 2019 of 238 m EUR. According to the data declared in the annual balance sheets, 3029 workers were employed at fish processing enterprises. Fish processing enterprises can be divided into two large groups – manufacturers of canned food and manufacturers of other fish products.

Historically, canned food producers have been in Latvia's territory (Ozolins *et al.*, 2018). Production was specially developed in the second half of the 20th century when Latvian enterprises began to supply Eastern Europe and the former USSR territory. The development of production was due to an inadequate distribution network and, as a consequence, the need for products with a long shelf life.

Due to restrictions on working with the customs union and socio-economic and demographic factors, the number of enterprises producing canned food has significantly decreased. By the beginning of 2020, there were 13 enterprises in Latvia, with a total turnover of 100 m EUR. Besides, already in 2020, two more enterprises ceased production.

The second group of enterprises is processors of raw materials, which they receive from the EU and countries outside the EU. Such processors, or simply importers, enter the local market and are re-exported in processed form. The turnover of the companies from the second group in 2019 is 138m EUR. The top 10 of these companies account for 85% of turnover (Table 1).

Both groups of companies (canned food producers and other fish processors) divide fish processing in Latvia into two practically equal groups – both in terms of turnover and companies. Both groups of companies were also affected by factors related to the pandemic. However, this influence was different due to the different situations of these companies.

On the one hand, fish processors producing products and canned fish, faced problems with the supply of raw materials, which to no small extent go for processing from abroad and often from outside the EU. Besides, processors faced declining demand for products with low shelf life.

On the other hand, both local and overseas demand for products with long shelf life has increased due to the epidemic. Historically, the Latvian industry has focused on producing such products in the form of canned fish. Given the increased demand, enterprises were able to load previously idle capacities. Until now, to a greater extent, enterprises have been able to maintain their activities and meet the growing demand. Nevertheless, the situation remains risky since canned food (primarily traditional canned food from local raw materials (small pelagics) is practically not mechanized and requires many people in one, which increases the risk of a rapid spread of the virus. Production of canned food from local raw materials significantly affects the increase in CO₂ emissions.

Production and processing have various high-level risks caused by the COVID-19 pandemic. Primarily traditional canned food, but also more modern – is characterized by a large concentration of people. All possible technical and organizational, and technological measures are needed to counter the current situation's risks. Investments are also needed in the means of protecting workplaces and transport of workers.

Table 1

The Top 10 Noncanned Fish Processors in Latvia in 2019

Company	Sales 2019, EUR	Employees	Characteristics
SIA 'Salas zivis'	29 556 893	124	Local, Baltic, EU, International wide variety.
SIA 'Atlas Premium'	26 760 793	143	Cod processing, mainly export.
SIA 'KH Select'	19 886 478	156	Salmon processing, mainly export.
SIA 'Venta FM'	9 866 492	31	Fish meal.
SIA 'RENETA'	6 069 172	39	Fish meal.
SIA 'Gardumu karaliste'	5 868 041	52	Local, Baltic wide variety.
SIA 'Mapetekš'	4 788 659	18	Fish meal.
SIA 'Atlantika Surimi Seafood'	4 233 933	58	Surimi.
SIA 'Taimiņš'	3 190 604	29	Local, Baltic wide variety.
SIA 'Sudrablīnis'	3 190 343	24	Roe, caviar.
All other companies	22 478 672	613	Wide variety.

Source: Authors' own based on data from Latvia Business Register, 2019.

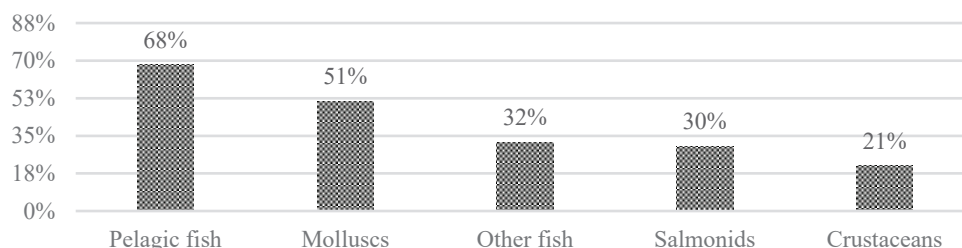


Figure 3. European Union's Self-Sufficiency Rate by Fish Commodity Group in 2017.

Source: Authors' calculations based on Eurostat and EUMOFA, 2020.

Moreover, all respondents confirmed additional costs related to regulatory changes and additional hygiene requirements. State support for the purchase of disinfectants and protection is possible.

The identified risks and possible measures go in line with those given in the documents issued by international organizations (FAO, 2020a).

Foreign trade. The value of EU trade of fisheries and aquaculture products, which comprises both extra-EU imports and exports, reached EUR 32.28 billion in 2018, making it the highest in the world. Of this, imports accounted for EUR 26.53 billion, which was 82% of the total. The EU is indeed a net importer, and the availability of these products in the domestic market mainly relies on extra-EU supplies. Low self-sufficiency of the EU in such a widely consumed species as Salmon (30%, Figure 3), can cause shortages due to additional controls and delays on the EU borders.

Latvia is closely linked to these flows, receiving most of the fish and fish products from abroad. The

overall trade balance shows that the countries outside the EU are more partners in marketing than supplying raw materials. Besides, total exports outside the EU and EEA account for only 22% of total exports and 7% of total imports.

Looking at the trade balances by fish species, we see that the EU and EEA countries provide the most significant raw materials supplied to Latvia. As for salmon, bearing in mind that Europe provides itself only for 30% (Figure 3), as well as the origin of the majority of imports from the EU – Sweden, Lithuania, Finland, and Poland – we can conclude that mainly Norwegian farmed salmon enters the Latvian market. Likewise, most of the cod for processing in Latvia comes from Sweden. However, the country of origin of the cod is Norway or Iceland. These two fish varieties cover most of the activities of two large fish portioning companies, some salmon canning companies, and local consumption. Mackerel, purchased from Iceland and Norway, is processed and supplied mainly to the EU and UK markets.

Table 2

Trade Balance of Latvia by Types of Raw Materials for the 2020 (January-August), EUR

Fish	EU	EEA + THE UK	Non-EU	Grand Total
Salmonids	-9 579 992	-4 647 403	1 637 247	-1 290 148
Miscellaneous aquatic products	-5 256 623	-284 733	-260 377	-5 801 733
Groundfish	-12 791 563	8 858 137	774 942	-3 158 484
Crustaceans	-2 444 450	-78 892	-209 157	-2 732 499
Other marine fish	-2 001 569	-350 566	-72 612	-2 424 747
Small pelagics (other)	327 594	-1 268 361	-29 708	-970 475
Tuna and tuna-like species	403 116	1 796	-1 062 374	-657 462
Freshwater fish	-405 306	16 380	-260 808	-649 734
Bivalves and other molluscs and aquatic invertebrates	-486 433	30 112	-187 834	-644 155
Flatfish	-134 025	-261 259	7 651	-387 633
Cephalopods	-235 378		-929	-236 307
Small pelagics (Mackerel)	16 500 912	-8397 294	79 059	8 182 677
Small pelagics (Sprat)	15 973 303	-1 403 422	20 902 844	35 472 725
Grand Total	-130 414	-7 785 505	21 317 944	13 402 025

Source: Authors' calculations based on Eurostat international trade statistics and EUMOFA.

Table 3

Trade Balance of Latvia by Type of Fish Processing Products for the 2020 (January-August), EUR

Fish	EEA + THE UK	EU	Non-EU
Frozen fish	-16 327 928	-13 720 265	2 832 037
Fresh or chilled fish	-1 070 994	-18 011 588	
Crustaceans	-60 771	-2 440 548	-5 699
Molluscs	30 352	-710 223	-188 850
Live fish		-202 819	-16 650
Aquatic invertebrates	-240	-8 661	
Fish fillets	5 868 394	-2 989 892	107 571
Fish, dried, salted, or in brine, smoked fish	56 498	5 684 308	-490 559
Prepared or preserved fish	4 247 136	32 801 974	18 684 563
Grand Total	-7 257 553	402 286	20 922 413

Source: Authors' calculations based on Eurostat international trade statistics and EUMOFA, 2020.

Receiving frozen and chilled fish from the countries of the free economic zone (Iceland and Norway), as well as the EU countries, the enterprises of the industry ensure domestic consumption, as well as send fish in processed form (cut fish, smoked fish, canned fish) as to the EU countries and countries outside the EU. In the first eight months of 2020, the total import volume was 116m EUR, and the export volume was 129 m EUR. Moreover, exports to countries outside the EU significantly exceeded imports (29.2 versus 7.8 m EUR).

Impact of COVID pandemic on foreign trade and apparent consumption

By comparing the trade balance by type of fish, we can assess the impact of the industry's current situation. The balance for fresh or chilled fish decreased in favor of an increase in frozen fish. The positive balance (more than exports than imports) for finished canned goods also increased.

Considering the change in exports and imports by types of fish (Figure 5) and processing types (Figure

6) separately, we find the crisis's main characteristics (lengthening of supply chains, possible closure of markets (Q in 2020). Such characteristics include Increased demand for products with an extended shelf-life; Reducing the use of fresh or chilled fish in favor of frozen; Decreased production of more expensive fresh salmon products; Decreased production of fresh or chilled food.

It is necessary to diversify the supply, accumulate the necessary stocks of raw materials, and adapt production capabilities to the lengthening of the supply chain for raw materials and distribution of goods to ensure the sustainability of the food system in international trade.

Risks associated with international trade include potential border delays and general market uncertainty.

The proposed institutional measures include both direct support to enterprises and the introduction of tax preferences.

Risks. Below is a summary of the average risk values (impact * likelihood) for producers and fishers.

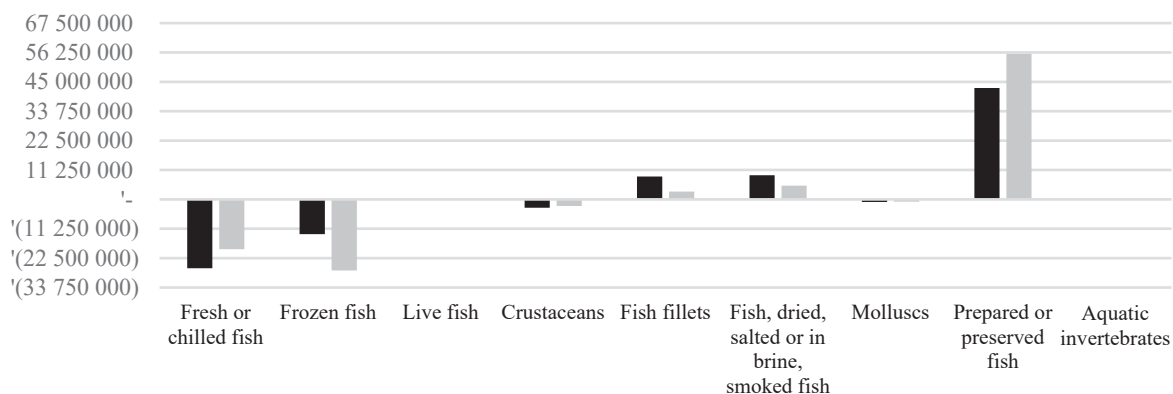


Figure 4. Trade Balance, 2019 (January-August) and 2020 (January-August) in Latvia, EUR.

Source: Authors' calculations based on Eurostat international trade statistics and EUMOFA.

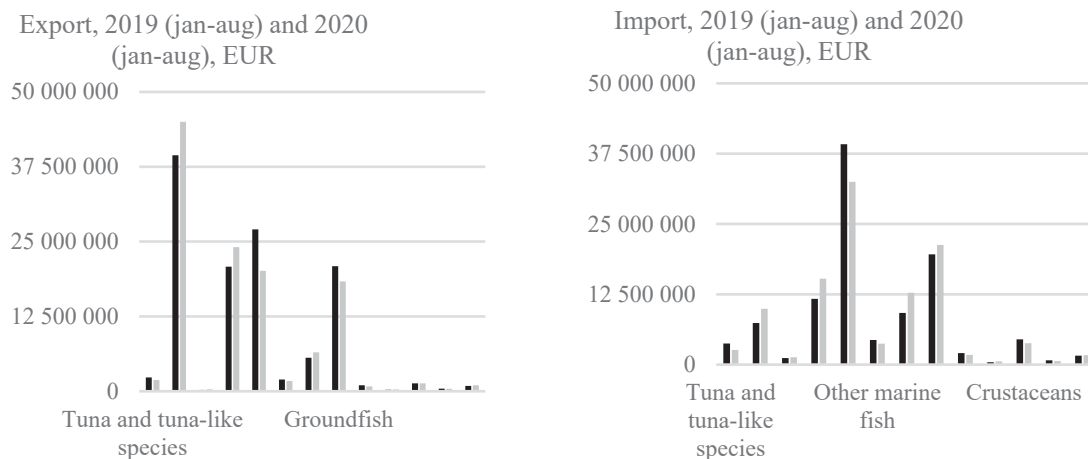


Figure 5. Trade Balance by Type of Fish in 2019 (January-August) and 2020 (January-August) in Latvia, EUR.

Source: Authors' calculations based on Eurostat international trade statistics and EUMOFA.

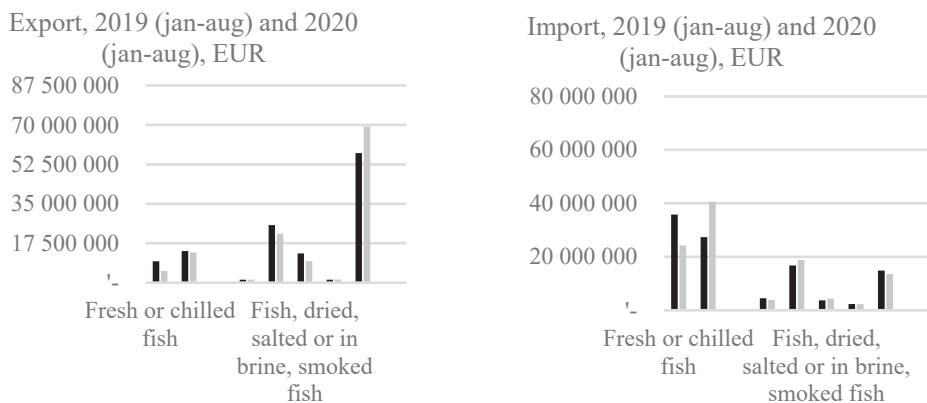


Figure 6. Trade Balance by Type of Fish Processing Products in 2019 (January-August) and 2020 (January-August) in Latvia, EUR.

Source: Authors' calculations based on Eurostat international trade statistics and EUMOFA.

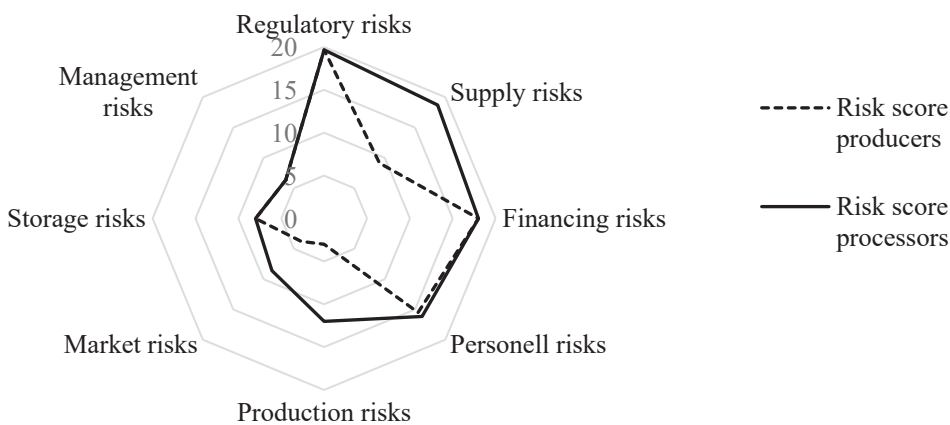


Figure 7. Risk Distribution in Fish Sector in COVID-19 Pandemic in Latvia.

Source: Authors' construction based on interviews with fish processors.

The perception of these risks coincides in almost all categories, except for the supply of raw materials (producers have no limited access to raw materials), as well as the risks associated with the organization of production (the organization of the catch is less susceptible to the risks of a pandemic).

It should be noted that some risks (highlighted in the Figure 7) have fundamental causes, and the COVID-19 pandemic has only highlighted bottlenecks in a sustainable food chain. In particular, the industry's dependence on manual labor (personnel risks) (European Commission Joint..., 2020), the dependence of local consumption on imported raw materials (supply risks), as well as the lack of production of a mass consumption product with an extended shelf life, to meet the changing needs of consumers (market risks).

Long-term support for the industry could be institutional measures to stimulate R&D aimed at creating products with an extended shelf-life as a more nutritious and sustainable alternative to canned food (Tan & Culaba, 2009). Moreover, such measures might stimulate the processing of local raw materials and promote the expansion of the range of products produced in the country to replace the import of fish with high added value. Finally, a long-term measure to strengthen the industry's sustainability could be to stimulate the automation and mechanization of processes currently employing a large number of people.

Conclusions

1. This article analyzes the identified risks and possible measures identified in the reCOVere-LV study. The key risks are the uncertainty of regulatory changes, risks associated with ensuring financial flow, and personnel risks. Besides, given some producers' dependence on imported raw materials, the supply risk is also significant.
2. This article uncovers the multidirectional effect of the COVID-19 pandemic on the fish sector in

Latvia. On the one hand, both in Latvia and abroad increased the consumption of products with extended shelf life (canned food). This allowed for the increase in the turnover of Latvian canned fish producers. On the other hand, factories that process imported fish were forced to switch from fresh to frozen raw materials to reduce the risk of product spoilage due to logistics delays.

3. The necessary institutional measures identified in the reCOVere-LV study include reducing producers and fish processors' costs for adapting to regulation changes, increasing financial stability, and ensuring the labor force's safe provision. Such measures include direct and indirect financial support, awareness-raising activities.
4. This article sets out the fundamental reasons for some of the risks. These fundamental reasons include the industry's dependence on manual labor, the production of a single product with the limited market within the country, and the lack of production of products that meet consumption habits changed by the pandemic. In particular – nutritious ready-made fish products with an extended shelf life. A measure aimed at addressing these fundamental industry problems could be facilitating access to R&D in automation and new product development by reducing transaction costs at all stages of development. However, the development of specific institutional mechanisms aimed at reducing fundamental risks requires further research.

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THE IMPACT OF THE COVID-19 PANDEMIC ON THE UNEMPLOYMENT RATE IN LATVIA

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Abstract

The economic and labour market consequences of Covid-19 were immediate, significant and lasting, with long-term negative effects on global economic development and activity in general. The global virus pandemic is having a profound effect on the labour market with a sharp rise in the number of unemployed, which are at high risk of becoming long-term unemployed as the pandemic drags on, some of whom will not return to the labour market. The outbreak of Covid-19 and the measures taken to combat it are leading to a rapid demand for unemployment benefits, but a large proportion of the unemployed registered with employment agencies are not actively involved in job search or do not want to establish an employment relationship at all. It is important to track and describe the major changes in the labour market around the world, but the restrictions that are being put in place to combat Covid-19 pose a huge obstacle to conventional data collection approaches and activities. Within the framework of this study, the unemployed in Latvia were interviewed in order to find out and evaluate the impact of the Covid-19 pandemic on the unemployment rate and the unemployed in Latvia. The aim of the article is to find out problems caused by the Covid-19 pandemic, which are related to the unemployed and which need to be solved in Latvia, and possibly also in other European and other countries of the world.

Key words: unemployed, unemployment rate, Covid-19, unemployment, unemployed women, long-term unemployment.

Introduction

The International Labour Organization (ILO) has issued a statement that the world of work is deeply affected by the global virus pandemic. It is not just the health of society as a whole that is at stake: economic and social conditions threaten the long-term livelihoods and well-being of millions. Both the ILO and national governments, workers and employers will have a crucial role to play in tackling the flammable crisis by ensuring the sustainability of businesses and jobs (ILO, 2021).

The ILO standard definition of unemployment reveals that unemployed are persons who are without work / a job and who have been actively looking for work in the last four weeks and are available to start work in the next two weeks. The outbreak of Covid-19 and the measures taken to combat it have led to a sharp increase in the demand for unemployment benefits throughout the European Union (EU). However, a large proportion of the unemployed who have registered with employment agencies are not actively involved in job search or are no longer available for employment, such as those who have to take care of a child who does not attend pre-school or school. This circumstance has led to a mismatch between the number of registered unemployed and the number considered unemployed according to the ILO definition (Eurostat Statistics Explained, 2021).

The economic and labour market consequences of Covid-19 were immediate, very significant now and are likely to be felt in the future. These consequences affect many millions of workers in many countries; some workers can continue working remotely, but there are also a significant number of people who

acknowledge that their standard of living has either fallen or that they have no income at all. Workers in the field of health or public safety are undergoing other changes, namely a significant increase in the workload in times of crisis. Official statistics from around the world are currently aimed at tracking and describing all these changes. The restrictions imposed to combat Covid-19 pose a huge obstacle to conventional data collection approaches and activities, and it is taking place at a time when there is a massive increase in the demand for information. The ILO has approached national statistical offices to find out the impact of Covid-19 on statistical activities in the field of labour statistics, mainly to find out the activities of the National Labour Force Survey. The aim is to share the information gathered so that countries can learn from other countries' experiences. The biggest challenge facing all countries is to maintain continuity and quality, while responding to changing circumstances and being flexible (ISOLAT, 2020).

Materials and Methods

Participants and Recruitment

In order to find out the impact of the Covid-19 pandemic on the unemployment rate in Latvia, a study was conducted, during which Latvian unemployed people were interviewed.

The survey was conducted by the research centre SKDS, which has been a member of E.S.O.M.A.R. (European Society for Opinion and Market Research) and operates in accordance with all the ethical and methodological rules and standards, set by that organization for public opinion and market research institutes. Since 2014, the research centre SKDS has

been represented in the WIN network of research companies (SDS, 2020).

The survey was completed by 216 unemployed people aged 18 and over. Data were collected in the time period from October 29, 2020 to November 2, 2020.

Starting from October 2020, the number of people infected with Covid-19 in Latvia increased significantly. If from 31 August 2020 to 6 September 2020 the number of infected persons increased by 1428, then at the beginning of October from 5 October 2020 to 11 October 2020 the number of infected persons was 2670, while from 2020 2 By November 8, 2020, the number of infected had already reached 8095 (COVID-19, 2021).

On November 6, 2020, the Cabinet of Ministers of the Republic of Latvia (RL) declared a state of emergency from November 9, 2020 to April 6, 2021. All on-site public events as well as private events and private gatherings were cancelled and prohibited, except for events within one household. Only those sports trainings (classes) that could take place outdoors were allowed - swimming pools, gyms, children's sports classes in the premises were closed, catering facilities were only allowed for take-out. Cultural venues and exhibition venues had been suspended. Beauty services were not provided, only grocery stores, pet shops, pharmacies were allowed to operate; however, the range of goods that could be sold was strictly regulated. Employers were obliged to provide employees with opportunities for remote work if the specifics of the work allowed it, as well as to organize work so that only those employees who ensured the continuity of work and could not do it remotely at their place of residence (LR Cabinet of Ministers, 2020).

Survey Development

Existing research and data on the unemployed were reviewed and informal talks with the unemployed provided information on problems and possible solutions. At the beginning of the survey, demographic information was clarified and only those respondents who were unemployed were selected with filter questions. It was initially determined whether the respondent had the status of a registered unemployed person or whether he / she was an unregistered unemployed person. This question was chosen because the State Employment Agency of the Republic of Latvia, similarly to the employment agencies of other countries, provides statistical data only on registered unemployment in the country. This article will report both the data obtained from the survey and the official statistics related to the purpose of the study.

Demographic characteristics included the age, gender, marital status, level of education, income,

nationality and region of residence. Specific answers to the questions were offered.

The seven questions in the survey focused on the circumstances of the Covid-19 pandemic. It was asked whether the Covid-19 pandemic was a reason for termination of employment, whether claiming registered unemployment was an employer's recommendation to receive unemployment benefits, whether the person planned to return to work with a previous employer, whether the Covid-19 pandemic has affected wage claims or has influenced attitudes towards employment.

Results and Discussion

In its January 2021 report, the World Bank predicts that, like previous economic crises, the Covid-19 pandemic will have lasting negative effects on global economic development and activity, as well as per capita income. The World Bank emphasizes the particular importance of institutional reforms to foster growth in the face of weak fiscal positions and rising debt. Only a comprehensive policy effort can restore stable, sustainable and equitable growth (World Bank, 2021).

EU countries are bound by Regulation (EC) No 1466/97 "Strengthening the surveillance of budgetary positions and the surveillance and coordination of economic policies". The purpose of this regulation is to prevent and coordinate the budgetary policies of the EU countries in order to ensure budgetary discipline within the EU. EU countries must submit stability programs to the European Commission, setting out medium-term budgetary objectives. The Commission evaluates the programs and the Council of Europe makes country-specific recommendations (EUR-lex, 2017).

According to the Latvian Stability Program for 2020–2023 with the global crisis caused by Covid-19 and the sharp decline in economic activity in Latvia in March and April 2020, the unemployment rate has started to rise sharply, in one and half months time or by April 17 with the number of registered unemployed increasing by 10,616 or 18.2% and the registered unemployment rate rising to 7.4%. According to the data of the Ministry of Welfare, by 17 April 2020, notices of collective redundancies had been submitted by 28 companies for a total of 4,118 employees. In turn, 15,064 employees have received downtime benefits since April 6. The number of vacancies, which rose sharply in 2019, fell sharply in March and April 2020, with the number of job advertisements on the recruitment company's CV Online portal declining by around 50% within one month by 17 April 2020.

The Covid-19 impact scenario assumes that due to the spread of the virus and measures to control it, the number of people employed in the economy will

decrease by an average of 45 thousand or 5% in 2020, losing part of the workforce in the directly affected sectors, including transport, trade, accommodation and catering, professional and administrative services. Accordingly, the unemployment rate in 2020 was expected to increase by 4.9 percentage points to 11.2% compared to 2019. In 2021 and 2022, as economic growth resumes, the number of employees will increase slightly, stabilizing at 883 thousand by 2023 (LR Ministry of Finance, 2020).

At present, it is not clear whether the optimistic forecasts of the Ministry of Finance of the Republic of Latvia on the resumption of economic growth in 2021, recorded in the Latvian Stability Program, will come true, as the emergency situation in Latvia has been extended until April 6, 2021 (LR Ministry of Health, 2021), and on February 24, 2021, the Minister of Health of the Republic of Latvia reports that if the rapid spread of a new strain of the virus, which was discovered in Great Britain and has already entered Latvia, occurs in Latvia, the government will decide to introduce even stricter security measures (Latvian Public Media, 2021).

The Latvian Stability Program of the Ministry of Finance also stated that the Covid-19 impact scenario has been developed under very high uncertainty and the risks of the scenario are downward (LR Ministry of Finance, 2020) and the increase in the unemployment rate set in the program to 11.2% in 2020 was not achieved (in December 2020 the actual unemployment rate was 8.2%), and such a percentage indicator was not achieved also in the beginning of 2021 (in January 2021 the actual unemployment rate was 8.8%) (Central Statistical Bureau, 2021); however, there is a tendency for unemployment to continue to rise.

216 unemployed Latvians in the age group of 18 to 63 participated in the survey of this study. The largest number of respondents is in the age group from 55 to 63 years (27.8%), followed by the group of respondents from 35 to 44 years (25.9%), while the

lowest number of surveyed unemployed is in the age group from 18 to 24 years (7.9%).

72.7% of women and 27.3% of men, respectively, participated in the survey. 49.1% of respondents have acquired secondary or secondary special education, a very similar number of respondents (43.1%) have higher education, while the unemployed with basic education this time are 7.9%. The majority of respondents identify themselves as Latvian (76.9%), 16.7% – Russians, 2.8% – Belarusians, 0.9% – Ukrainians and the same number of Poles, 0.5% Lithuanians and 1.4% chose the answer “other”. 93.1% of respondents are Latvian citizens and 6.9% of respondents do not have Latvian citizenship. 61.6% of the unemployed indicated that they were unemployed as their main occupation, 11.6% indicated that they were students, while 26.9% identified themselves as a housewife / househusband.

The World Bank points out that a package of reforms aimed at investing in human capital, physical capital and increasing women’s participation in the labour force could help address the expected negative effects of the pandemic and boost potential growth over the next decade (World Bank, 2021).

The results of the study indicate that the majority of respondents to the survey are women (72.7%).

According to the SEA data of the Republic of Latvia, at the end of December 2020, 54.9% (38,185) of the total number of registered unemployed (69,605) were women and 45.1% (31,420) were men (NEA, 2020). Although the difference in the number of registered unemployed by gender is not as cardinal as found in the study, it is important to clarify that the NEA offers statistics only on the registered unemployed, while the study also included unregistered unemployed, some of whom did not intend to cooperate or do not cooperate with NEA. Given the fact that the study found that a relatively large number of unemployed do not plan to enter employment, it is important to pay attention not only to long-term unemployment, but also in line with the World Bank’s findings, it is necessary

Table 1

Distribution of respondents by age groups

		Age			
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	18 – 24	17	7.9	7.9	7.9
	25 – 34	34	15.7	15.7	23.6
	35 – 44	56	25.9	25.9	49.5
	45 – 54	49	22.7	22.7	72.2
	55 – 63	60	27.8	27.8	100.0
	Total	216	100.0	100.0	

to pay more attention to women's participation in the labour market.

The job losses caused by the Covid-19 crisis are affecting women the most. Women are represented in the sectors most affected, such as leisure and hospitality, healthcare and education, and in many of these areas women are losing their jobs at a disproportionate rate. Labour experts are rightly concerned that, even after the resumption of work and the end of the state of emergency in the countries, many workers, especially in the leisure and hospitality sector, will continue to suffer losses of working hours and income. Economists acknowledge that low-paid workers are the least hired, with a disproportionate number of women (Washington Post).

The ILO points out that, from an economic point of view, reducing the gender gap in labour force participation could significantly increase global GDP. Growth would be huge in the countries with the largest gender gaps, but in many developed countries, annual GDP growth would also increase, which is important in times of almost zero growth.

ILO in partnership with Gallup, Inc. (American analytics and consulting firm) found that 70% of women, regardless of their employment status, prefer to have a paid job (ILO, 2018).

Of the unemployed who took part in the survey, 81% said that the Covid-19 pandemic was not a reason for termination of employment, 8.3% said that the Covid-19 pandemic was a reason for termination of employment, and 10.6% said that the Covid-19 pandemic was partly the reason for the termination of employment.

Respondents who acknowledged that Covid-19 was or was in part a reason for termination of employment also answered the question of whether to apply for registered unemployment status and receive unemployment benefits was recommended by the employer. 0.9% admitted that they received such an employer's recommendation, 6.5% indicated that obtaining the status of registered unemployed was not an employer's recommendation, while 1.9% indicated that it is difficult to say whether such an employer's recommendation was received.

Respondents who acknowledged that the Covid-19 pandemic played a role in making them unemployed also answered the question of whether they plan to return to work with their previous employer if they receive such an offer. 39% admitted that they plan to return to the previous employer and 61% indicated that they do not.

The situation where the unemployed apply for the status of registered unemployed in order to receive unemployment benefits, but do not plan to look for a job because they will return to work as soon as the previous employer can resume full-fledged

economic activity can be explained by the fact that, although the Cabinet of Ministers of the Republic of Latvia issued Regulations on employers affected by the Covid-19 crisis, which qualify for downtime benefit and distribution of overdue tax payments for periods or deferral for up to three years (Cabinet Regulations, 2020), and the purpose of these rules was to compensate for the loss of income in the Covid-19 crisis by providing a downtime allowance for workers and the self-employed, the criteria set out in the rules proved to be too strict. Already by May 2020, amendments were made twice to the relevant regulations of the Cabinet of Ministers and the criteria for receiving the downtime benefit were relaxed. Companies could start applying for downtime allowance from March 25, 2020, and by May 12, 3944 companies received denials of downtime allowance (8249 companies were granted downtime allowance) and in 1816 cases the benefit was refused to the self-employed, who could start applying for the downtime benefit from 3 April to 12 April (granted to 2856 self-employed) (LV portal, 2020).

It should be noted that although the Regulations of the Cabinet of Ministers of the Republic of Latvia on employers affected by the Covid-19 crisis, who qualify for downtime benefit and distribution of overdue tax payments for periods or deferral for up to three years, were amended several times, on January 1, 2021 they lost their validity and were replaced by the Regulations on Support for Downtime of Taxpayers for the Continuation of Their Operations in the Conditions Caused by Covid-19, which entered into force on 28 November 2020 (Regulations of the Cabinet of Ministers, 2020).

In response to the questionnaire, respondents expressed their views on whether the Covid-19 pandemic had affected their wage demands. All 216 respondents answered this question, and the majority of respondents (39.4%) answered that they plan to find a job with equal pay, 14.8% of respondents stated that they are ready to work for lower pay, 15.7% of respondents are aiming to find a job with a higher wage, while 30.1% of the unemployed answered that they do not plan to enter into employment at all; therefore, there is a good reason to believe that these unemployed will become long-term unemployed. For a more detailed analysis of this issue, I performed a cross-tabulation analysis comparing the positions of men and women. The Covid-19 pandemic has affected 33.9% of men, 13.6% of whom want to find a better paid job, while 20.3% will agree to work in a lower paid job than before the Covid-19 pandemic. The Covid-19 pandemic has also changed the position of 29.3% of women surveyed against pay: 16.6% are aiming to find a better paid job, while 12.7% of women, on the

Table 2

Distribution of women's and men's answers to the question "Has the Covid-19 pandemic affected your pay claims?"

Yes, I plan to find a better paid job Yes, I am also willing to receive a lower salary			Has the Covid-19 pandemic affected your pay claims?				Total
			No, I plan to find a job with equal pay	I do not plan to enter an employment relationship			
Your gender	Male	% within Your Gender	13.6%	20.3%	42.4%	23.7%	100.0%
		% within Has the Covid-19 pandemic affected your pay claims?	23.5%	37.5%	29.4%	21.5%	27.3%
		% of Total	3.7%	5.6%	11.6%	6.5%	27.3%
	Female	% within Your gender	16.6%	12.7%	38.2%	32.5%	100.0%
		% within Has the Covid-19 pandemic affected your pay claims?	76.5%	62.5%	70.6%	78.5%	72.7%
		% of Total	12.0%	9.3%	27.8%	23.6%	72.7%
Total		% within Your gender	15.7%	14.8%	39.4%	30.1%	100.0%
		100.0%	100.0%	100.0%	100.0%	100.0%	
		15.7%	14.8%	39.4%	30.1%	100.0%	

contrary, will agree to work for a lower wage. 42.4% of men and 38.2% of women nevertheless want to find a job with equal pay. On the other hand, 23.7% of men and 32.5% of women do not plan to enter employment at all.

18.5% of the unemployed, who admitted to being affected by the Covid-19 pandemic, indicated that they would like to work in a paid state in the future, 6.6% indicated that they wanted to work in a private sector company, but 74.8% of the unemployed indicated that The Covid-19 pandemic has not affected their position towards a future employer, and it does not matter whether it will be a public or a private sector employer.

The next two questions focused on whether the unemployed who participated in the survey plan to cooperate with the National Employment Agency (NEA). In accordance with the Law on Unemployment and Support Seekers of the Republic of Latvia, the NEA implements the state policy in the field of reducing unemployment and supporting the unemployed, as well as job seekers and persons at risk of unemployment. The NEA not only registers and counts the unemployed and jobseekers, but also organizes a dialogue between the unemployed and employers to reduce unemployment, as well as organizes or implements active employment measures and preventive unemployment reduction

measures (LR Unemployed and Jobseeker Support Law, 2002).

When asked whether the unemployed plan to cooperate with the NEA in order to find a job, 20.4% answered that they plan to actively cooperate with the NEA, 13.4% indicated that they are forced to cooperate in order to maintain their registered unemployment status and receive unemployment benefits, 43, 1% of the unemployed indicated that they do not plan to cooperate with the National Employment Agency with the aim of finding a job, because they plan to find a job on their own or with the help of friends and relatives, and 23.1% indicated that they do not plan to cooperate with the NEA.

As indicated above, the NEA not only registers and counts the registered unemployed, but also, in cooperation with other state and local government institutions, as well as natural and legal persons, organizes and implements active employment measures and preventive unemployment reduction measures (Cabinet Regulations, 2011). The NEA organizes the following employment or preventive measures: vocational training, retraining or upgrading of qualifications, acquisition of non-formal education, training with an employer, development of skills necessary for work, measures to increase competitiveness, measures for certain groups of persons, paid temporary public work (community

service), support measures for people with addiction problems, student summer employment events, career counselling. The most used measures are career counselling, which was implemented 52,308 times in 2020; however, the acquisition of non-formal education (10,982 times in 2020) and paid temporary public work (8,994 times in 2020) are also quite actively used (NEA, 2020).

The unemployed participants in the study, who admitted that they had decided to cooperate with the NEA, also answered the question whether they had also applied for an active employment measure. 74.7% of these unemployed answered that they did not use such an opportunity and did not apply, while 25.3% of the unemployed applied for active employment measures. The unemployed people who applied for active employment measures offered by the NEA were asked to indicate which of the NEA's offers they had decided to use. 16 respondents indicated that they have applied for the courses offered by the NEA; one respondent indicated that they have applied for a professional development education program, two respondents have applied for community service, one respondent has applied for a motivation program, two respondents have applied for career counselling and one respondent stated that "hard to say" what event he has applied for.

The study identified 30.1% of the unemployed who admitted that they did not plan to enter into an employment relationship at all. These respondents can reasonably be considered as existing long-term unemployed or as unemployed who will become long-term unemployed in the future.

The World Bank predicts that, after more than twenty years of reducing global poverty, the current crisis will restore poverty to its last level in 2017. The growth of human capital is reduced by long periods of unemployment. Covid-19 could also hinder the development of human capital. Longer periods of unemployment can both discourage workers from remaining in the workforce and discourage the unemployed from entering employment, which also has a negative impact on the skills of workers and the unemployed. Past economic crises have shown that reduction of skills development widens income disparities (World Bank, 2021).

Long-term unemployment (when a person is unemployed for more than 12 months) can have serious negative consequences for the individual, society and its economic system. People who are out of work for a long time find it harder to find work over time. Some also face lower earnings and limited career prospects. Workers' human capital (actual or perceived by the employer) may deteriorate or become obsolete during long-term unemployment.

In addition, the time and willpower spent looking for work tends to decrease. Both elements suggest that the probability of leaving unemployment decreases significantly with the duration of unemployment, which in turn increases the probability of staying unemployed. Over time, as unemployment continues, the long-term unemployed are likely to leave the labour market and retire or become members of a program for people with disabilities. At national level, high long-term unemployment jeopardizes overall employment policy goals, lowers access to decent work and lowers occupational and geographical mobility (Bejaković & Mrnjavac 2018).

The causes of long-term unemployment are structural unemployment and cyclical unemployment. The recession leads to a massive increase in cyclical unemployment. Those who cannot find work become long-term unemployed. If they are out of work long enough, their skills become obsolete. Over time, this contributes to structural unemployment. They have less money to spend, which reduces consumer demand. This further slows economic growth, leading to more cyclical unemployment (Amadeo, 2021).

Conclusions

1. To increase GDP, it is necessary to increase women's participation in the labour force. Support measures for women should be provided both by the NEA and other state and local government institutions, as the number of unregistered unemployed women is high.
2. In order to prevent the unemployed from registering with the NEA only to receive unemployment benefits and do not plan to look for work, thus wasting NEA resources, it is necessary to improve the rules for granting downtime benefits to all employees who plan to work for their current employer when they are able to resume full-fledged economic activity.
3. Increased attention should be paid to the unemployed who have become or are at risk of becoming long-term unemployed, while maintaining and improving, as far as possible, the job skills of the unemployed in line with labour market requirements.

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TRANSPORTATION, LOGISTICS AND REGIONAL DEVELOPMENT IN COVID-19 ERA: MODELLING SECTORAL SHOCKS CAUSED BY POLICY AND SAFETY MEASURES




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Abstract

COVID-19 policy and measures have caused both negative and positive challenges for the transport sector. The aim of the research is to model an impact of shocks that transport and logistics encounter during the COVID-19 era on the economy and regional development. A comparative-static approach that involves an input-output model with additional regional modelling block and scenarios are applied. Two scenarios are estimated for Latvia's economy: firstly, extremely dramatic decline in demand on air transport services by 90%; secondly, unexpected increase in demand for postal and courier services that doubled output. The results of the first scenario argue that the service sector is influenced more than manufacturing due to air transport collapse –rental and leasing services (-11.6%), employment services (-9.7%), other transport services (-7.0%), impact on manufacturing is relatively minor and only on certain branches. The results of the second scenario on doubled output in postal and courier services argue that there is a positive impact, but the scale is relatively low, the most affected industries are manufacturing (of paper products (increase by 1.7%), rubber and plastic goods (1.6%)). The findings confirm that the urban areas due to higher economic activity and larger service sector are more affected to the modelled shocks both negative and positive. The rural areas are relatively less negatively affected during the crisis, but at the same time, during the recovery (for example, in the post-COVID era) it may lead to weaker economic activity and the rural areas will continue to lag behind urban areas.

Key words: modelling, COVID-19 shocks, regional development, rural areas, transport, logistics, input-output analysis.

Introduction

Economic impact of COVID-19 has received a lot of research attention. A number of recent studies have examined various aspects of COVID-19 era restrictions, limitations, policies, direct and side effects and various impacts, including economic impacts. Considerable research attention has been directed towards COVID-19 impact on supply-chains, transport, logistics, delivery organisation and management. The recent findings (Gray, 2020) outline that the pandemic and the measures to address the pandemic have created significant new challenges for transportation system. These challenges include both negative (restrictions, risks, additional costs, lockdowns etc.) and positive (unexpected booming of niche industries, as courier services, online services, take-away food deliveries, etc.) activities.

It is generally agreed that COVID-19 is a new phenomenon that is under ongoing studies. Kim (Kim, 2021) outlines that the knowledge of COVID-19 impacts on transportation and society continues to evolve and progress, and at the same time he concludes that a wide range of different theoretical approaches and analytical techniques, methods, styles of research, even new type of data sources (as mobile phone location data) can be used in interdisciplinary research.

Transport and logistics sectors have been influenced differently, not only by policy measures but also by customers' unpredictable behaviour. Even studies in relatively stable transport sectors as public transportation (Tirachini & Cats, 2020) outline great

challenge for contemporary public transportation worldwide, resulting from an unprecedented decline in demand and revenue. The study (Wielechowski, Czech, & Grzęda, 2020) assesses the changes in mobility in public transport in one country (Poland) caused by the COVID-19 pandemic from the country and regional perspective and the findings reveal a negative but insignificant relationship between human mobility changes in public transport and the number of new confirmed COVID-19 cases; however, the strength and statistical significance of the correlation significantly varies regionally.

Regional perspective is an important issue to take into account as development differs in urban and rural areas. The results of the study (Wen, Sheng, & Sharp, 2021) on the impact of COVID-19 on changes in community mobility and variation in transport indicates that regional heterogeneity in the variation of public transport use was evident in New Zealand. Of all the transport modes, air transportation had faced extremely severe limitations, flight restrictions and other policy measures. The studies (Sobieralski, 2020) argue that recovery following uncertainty shocks is estimated to take between four and six years. Air transportation in various regions has undergone various impacts. The authors (Sun, Wandelt, & Zhang, 2020) outline that Europe has undergone probably the most significant changes regarding domestic flight network connectivity, while the United States suffered less severely and China is recovering. The authors (Sun *et al.*, 2020) conclude that the evolutionary dynamics

of domestic airport networks are strongly correlated with the COVID-19 situation in each country.

However, the recovery highly depends on customers' decisions and behaviour, especially in air transportation. Several researchers (Monmousseau *et al.*, 2020) analysed the effect of the travel restriction measures caused by COVID-19 pandemic from a passenger perspective on USA air transportation system. Four passenger-centric metrics (empathy score, sentiment gap, quality response, quantity response) were proposed and extracted from passenger-generated data as these data could be gathered earlier than official flight data (Monmousseau *et al.*, 2020).

Passenger transportation is closely linked with tourism industry. As cruise tourism was paused as a result of the COVID-19, the studies offer innovative and adaptive solutions to new reality. For example, Renaud (Renaud, 2020) argues to promote the development of a niche cruise tourism industry with small ships; however, he stresses that mass cruise tourism industry will do everything in its power to regain its hegemonic position. Tourists expectations have huge impact on decisions and spending, for example, the study on impacts of COVID-19 crisis over the tourism expectations in Azores Archipelago (Couto *et al.*, 2020), where tourism is a strategic sector for the regional economy and growth, argues that the paradigm of persons attitudes in choosing the time and form of vacation has substantially changed. Regarding tourism industry, probably the only certainty for this industry is that nothing will be like it was in the pre-COVID-19 era (Renaud, 2020). This idea is shared by many other studies.

The negative aspects are more examined and assessed rather than positive aspects regarding conditions and restrictions in COVID-19 era. The study (Abel & Gietel-Basten, 2020) outlines that tightening of international borders during and after COVID-19 pandemic has a significant impact on international labour force migration and international remittance flows. In result, the authors (Abel & Gietel-Basten, 2020) stress that negative health, economic, social or political changes for labour migrants in one territory will have profound consequences far across the world. The results of Italian case (Giammetti *et al.*, 2020) suggest that by stopping the production process of many key sectors, the lockdown has led to a drop in input and output that, in turn, has generated a lock of about 52% of total circulating value added, 30% of which has been locked within indirect value chains. Some sectors and economic agents in the economy even gain, for example, Gray (Gray, 2020) has found that the reduced demand for transportation services in most other sectors of the economy reduce transportation costs and increase transportation availability for most agricultural supply chain.

Studies examine the further development in post-COVID era. The study (Collier & Mayer, 2020) examines the promotion of small and medium-sized enterprises post-COVID in the provinces of the United Kingdom focusing on how reforming one certain system (in this case, financial system) promotes regional development. Sustainable regional development ensures urban-rural income convergence reducing the income gap and income inequality in rural areas compared with urban areas (cities and towns) (Auzina-Emsina & Ozolina, 2019) that are mighty motivators for youngest generation to stay in rural areas in developed countries. The study on 65 countries (Young, 2013) argues that one out of every four or five individuals raised in rural areas moves to urban areas as a young adult in order to increase net income and actually earns more than rural population that has not migrated. Regional development is closely linked with migration both national and international.

COVID-19 pandemic impact on various aspects has been investigated by a wide range of methods. Input-output approach (alone or incorporated in models) is used in numerous researches. The recent study (Bonet-Morón *et al.*, 2020) uses input-output model and scenarios analysis, the results indicate that depending on the scenario considered, accommodation and food services, real estate, administrative services, construction and trade are the most affected sectors. The study of (Giammetti *et al.*, 2020) employ techniques of complex networks analysis and input-output traditional tools, the study identifies key affected sectors. Complex study (Lenzen *et al.*, 2020) on global socio-economic losses and environmental gains from the coronavirus pandemic uses a global multi-regional macro-economic model that is capable to capture direct and indirect spill-over effects – social, economic and environmental effects. New circumstances and new conditions introduce new and innovative data use. Mobile positioning data provided at a high spatial granularity (up to NUTS3) are used analysing the impact of COVID-19 confinement on mobility in Europe (Santamaria *et al.*, 2020).

Researches devoted to modelling regional development and impact on certain regions in countries reveal that policy is a key element. The study on Italian regions (Arbolino & Caro, 2020) argues that the COVID-19 shock is producing the major adverse effects on regional labour markets in certain regions (in the South Italy) and on female occupations. The authors stress the impact of the European Union (EU) funded projects that should be addressed to reduce the vulnerability of labour markets and occupations that show low resistance to shocks and weak recoverability (Arbolino & Caro, 2020). The literature review indicates that regional development deserves more research attention.

The aim of this research is to model an impact of shocks that transport and logistics encounter during the COVID-19 era on the national economy and regional economic activity. For this purpose a comparative-static approach that involves an input-output model with additional regional modelling block and scenarios, is applied. The research involves the analysis and detection of current trends in the EU regarding transport sector, input-output model building, elaboration of scenarios assumptions, and modelling the results. The literature review and findings suggest that sophisticated systematic and modelling tools give accurate and valuable results.

Materials and Methods

In the research, the high level of sectoral disaggregation of the economy is used that is based on the classification of economic activity (NACE) Rev.2. that subdivides the economic activity into 64 industries. Transport is classified according to H industry that consists of: Land transport and transport via pipelines (NACE code H49), water transport (H50), air transport (51), warehousing and support activities for transportation (H52), and postal and courier activities (H52). As a result, the elaborated input-output model computes the results for 64 economic activities.

In order to reveal various aspects and observe the phenomena from different perspectives, the regional development is analysed and modelled by two approaches. Firstly, regional development is analysed according to NUTS3 level. Latvia is subdivided into six regions according to NUTS 3 level: Riga, Pieriga, Kurzeme, Zemgale, Vidzeme, and Latgale. Secondly, the urban-rural typology of Eurostat (Eurostat, 2018) is applied that classify regions into: predominantly urban regions, intermediate regions, predominantly rural regions.

The research is based on the EU data and Eurostat classification. The research period is 2015–2020 (or till latest statistics available). The research uses the latest available symmetric input-output (product-to-product) table of 2015 that is actually a set of tables, including domestic input-output and import input-output tables. According to Eurostat, national statistical offices can prepare symmetric input-output tables in product-by-product or in industry-by-industry approach. The majority of the EU countries prefer the product-to-product approach for symmetric input-output tables. The set of input-output tables offers valuable information for static analysis, but it is impossible to analyse dynamics or perform comparative-static analysis.

The impact of sectoral shocks is modelled as the scenario analysis applying input-output model. In this research, the impact and the so-called what-if scenarios are evaluated in short term and medium term hence technological coefficients are constant. The what-if scenarios allow to estimate the quantitative effect of a certain (or given) change in the economy. The elaborated input-output model includes the basic identities that ensure the equilibrium in the economy and additional regional development modelling block.

The modelling process includes several stages: firstly, the direct and indirect impact modelling using main input-output model, obtaining results for 64 economic activities. Secondly, the values are aggregated into 10 major NACE groups (NACE codes: A, B-E (except F), E, F, G-J, K, L, M-N, O-Q, R-U) and used for regional development modelling block – both, firstly, compute the sectoral economic activity in six regions, sum the results and obtain the certain region's totals by bottom-up approach; secondly, compute the sectoral economic activity in predominantly urban regions, intermediate regions,

Table 1

**Transport dynamics in the EU and Latvia in 2016-2019
(value added, chain linked volumes, index 2015=100)**

Industry/Time	European Union – 27 countries				Latvia			
	2016	2017	2018	2019	2016	2017	2018	2019
Total – all NACE activities	101.9	104.8	107.0	108.6	101.8	105.1	108.7	111.3
Transportation and storage	100.8	105.1	108.0	110.2	101.7	108.3	112.6	109.6
Land transport and transport via pipelines	100.3	104.4	106.8	:	102.3	110.9	106.1	:
Water transport	104	107.4	110.2	:	95.0	91.7	85.5	:
Air transport*	103.2	114.7	127.1	:	123.9	153.9	185.3	:
Warehousing and support activities for transportation	101.3	105.9	108.9	:	94.8	95.5	97.9	:
Postal and courier activities	97.8	97.3	95.7	:	95.3	98.9	108.6	:

: no data available; * For Latvia, the data on output dynamics are given due to classification updates and observable breaks in series.

and predominantly rural regions, sum the results and obtain the certain area's totals by bottom-up approach.

The research data analysis covers the whole EU, but modelling is executed on the case of one EU country – Latvia. The method and the scenarios are applicable to the EU countries facing similar research questions.

Results and Discussion

Transport sector has experienced a stable and industry-wide development in 2015–2019 in the EU, as well as in Latvia. According to the Eurostat data, the transportation and storage has grown faster than the total EU economy. In recent years air transport has been influenced by various factors that resulted in dynamics of chain linked volumes both in the EU and Latvia with extremely high index values (see Table 1).

The COVID-19 conditions and policy measures that were introduced in early 2020 significantly shocked the transport sector, especially the severe limitations were applied to air transport. It resulted in output decline by 90% or more if compared with a year before. According to the Eurostat (Eurostat, 2020) data, the number of passengers carried decreased by more than 91% in 20 EU countries in the second quarter 2020 compared with second semester of 2019: the largest decreases in numbers of passengers were observed in Spain (-99%), Germany (-97%), France (-97%). All EU airports registered a dramatic fall in the number of passengers handled. Due to the COVID-19 related strict trade limitations, introduction of severe safety restrictions and activities, even lockdown of cafes, restaurants, etc. in many EU countries that resulted in e-commerce boom and increase of postal and courier delivery services in all EU countries.

However, the pattern of recent development was significantly impacted by policy measures, restrictions regarding certain sectors in the economy in all EU countries. The most severe restrictions and limitations were applied to air transport, hotels and recreations, restaurants, cafes, public events, etc. sectors. Many governments introduced the support and compensations mechanisms and additional funds. However, it is valuable to estimate the impact on the economy if these support actions have not been introduced. Hence, in the research, the shock scenario analysis is applied.

To model the impact of sectoral shocks caused by policy and safety measures in COVID-19 era, evaluating the macroeconomic, sectoral and regional perspective, two comparative-static scenarios are estimated taking into account the above-detected trends and assumptions (based on data analysed) in Latvia's economy:

- 1) air transport services (NACE code H51) experience a dramatic demand decrease by 90%

(due to policy measures and flight restrictions), it is assumed that the general consumption pattern and routine is constant as it is an unexpected short-term shock with unknown length of impact. The society believes that it will soon be over. The other indicators (as regional allocation of economic activity by NUTS 3 level and economic activity by urbanisation of area, etc.) are unchanged – *ceteris paribus*. This scenario involves computing the impact on shocked industry, computing direct and indirect impact on other industries (64 industries), on the basis of computed sectoral development results, the impact on six regions (NUTS 3 level) is computed, how it has affected the economic activity in cities, towns, suburbs, and rural areas. The scenario illustrates the impact of collapse of one industry on the rest of the economy in different perspectives without government compensation mechanisms or support programs;

- 2) Output of postal and courier services (NACE code H53) doubled due to the government restrictions and safety measures regarding shops, markets, etc. and households and business tend to maintain the consumption pattern as used, consume the goods (including food and beverages, materials, electronics, etc.) but buy more goods online (or use other distance shopping options) with delivery. The courier services and pickup point services experience overload. However, it is an unexpected short-term shock with unknown length of impact for both economic actors – households and courier and postal service companies. At the same time, the general belief is that it soon will be over. The other indicators (as regional allocation of economic activity by NUTS 3 level and economic activity by urbanisation of area, etc.) are unchanged – *ceteris paribus*. This scenario also involves computing the impact on shocked industry, computing direct and indirect impact on other industries (64 industries) and the impact on six regions (NUTS 3 level), and how it has affected the economic activity in cities, towns, suburbs, and rural areas. The scenario demonstrates the impact of demand increase observed in one industry on the rest of the economy in different perspectives without additional government compensation mechanisms or support programs. The aim is to estimate the impact of relatively forced decisions (caused by restrictions allowing to buy online but not in shop) made by economic agents on the economy.

The selected and modelled above-given scenarios illustrate that in any economic crisis there are industries that experience dramatic decline and at the same time there might be specific industries or niches that have hard times to manage the overload and overdemand situation. And both extreme cases can be

Table 2

Modelling results of the first scenario representing sectoral output change (%)

NACE/CPA CODE	Product or service	Impact
H51	Air transport services	-67.3%
N77	Rental and leasing services	-11.6%
N78	Employment services	-9.7%
C30	Other transport equipment	-7.0%
H52	Warehousing and support services for transportation	-6.8%
C22	Rubber and plastic products	-5.4%
N79	Travel agency, tour operator and other reservation services and related services	-5.3%
C20	Chemicals and chemical products	-3.3%
J62_63	Computer programming, consultancy and related services; Information services	-3.0%
C24	Basic metals	-2.5%

observed even in one economic sector – in transport services (according to NACE H industry) all at once. COVID-19 caused conditions allowing that long-time unexpected shock could come about, which is even relatively unusual to economic modelling community and scenario analysis.

The results of the first scenario estimated by the input-output model claim that the impact on the economy is clearly observable and noticeable. The total final consumption expenditure of households decreases by 1.3%, the overall national economic decline is estimated by -1.1%.

Air transport services are interlinked directly and indirectly with many domestic industries as well as consume large amount of imported goods, only the major impacts are analysed in detail. Table 2 shows the modelled full (direct and indirect) impact results of product output changes that are larger than -2.5%

(output of products with the impact below 2.5% are not included in the Table 2) and represents ten industries that are the most affected. If private persons travel only due to significant reasons (as re-emigration flights home, re-union of family, death of relative, etc.), due to government restrictions results in collapse of the industry (output decline by -67.3%); at this point, it is worth to stress that this scenario assumes that commercial cargo and human aid, etc. flights are unshocked.

The modelling results show that service sector is influenced more than manufacturing – for example, rental and leasing services (-11.6%), employment services (-9.7%), other transport services (-7.0%), warehouse, etc. services (-6.8%), travel agencies (-5.3%), as compared to manufacturing of rubber and plastic products (-5.4%), Chemicals and chemical products (-3.3%), basic metals (-2.5%).

Table 3

Modelling results of the second scenario representing sectoral output change (%)

NACE/CPA CODE	Product or service	Impact
C17	Paper and paper products	1.7%
C22	Rubber and plastic products	1.6%
N77	Rental and leasing services	0.5%
H52	Warehousing and support services for transportation	0.5%
C20	Chemicals and chemical products	0.4%
N80_82	Security and investigation services; services to buildings and landscape; office administrative, office support and other business support services	0.4%
J58	Publishing services	0.4%
H51	Air transport services	0.4%
M69_70	Legal and accounting services; services of head offices; management consultancy services	0.4%
J62_63	Computer programming, consultancy and related services; Information services	0.3%

Table 4

Modelling results of the two scenarios representing regional output change (%)

Scenarios/NUTS3	TOTAL	Riga	Pieriga	Vidzeme	Kurzeme	Latgale	Zemgale
First scenario	-1.14%	-1.29%	-1.14%	-0.85%	-0.97%	-0.86%	-0.86%
Second scenario	0.48%	0.51%	0.53%	0.35%	0.46%	0.41%	0.37%

Table 5

Modelling results of the two scenarios representing output change in territories regarding level of urbanisation (%)

Scenarios/Territory	TOTAL	Predominantly urban regions	Intermediate regions	Predominantly rural regions
First scenario	-1.14%	-1.29%	-1.03%	-0.85%
Second scenario	0.48%	0.51%	0.48%	0.36%

The results of the second scenario estimated by the input-output model claim that impact on the economy is noticeable but with lower impact level as in the first scenario as the analysed industry (postal and courier services) is supplementary service activity, and it has a smaller share in the economy. As a result, if postal and courier services experience a doubled demand, the total economic activity increases by 0.5%. As domestically produced and imported goods can be delivered, the impacts on national industries are various. Table 3 shows the modelled full (direct and indirect) impact results of product output change that are larger than 0.3% (output of products with the impact below 0.3% are not included in Table 3) and represents ten industries that are the most affected.

The postal and courier services consumes relative low share of intermediate goods of other domestic industries and have relatively high proportion of labour costs in the costs structure. And, in this case, the modelling results show that even extremely positive impact on this industry doubling the demand does not significantly affect the rest of the economy. No doubt, there is a positive impact, but the scale is relatively low. The results claim that the most affected industries are manufacturing of paper products (output increase by 1.7%), rubber and plastic goods (1.6%) and supportive services industries as rental and leasing services (0.5%), warehousing and support services for transportation (0.5%). Other industries have an impact that is lower than 0.4%.

Within the modelling scenarios it is worth to stress the specific of one industry coke and refined petroleum products (C19) due to the fact that it is almost completely import based industry and any, even minor, changes generate unreasonably high changes but in absolute figures the change is minor.

Regional economic activity depends on various factors (as availability of resources, infrastructure, skilled labour force, production traditions and history, etc.), it quite varies among different regions; and hence economic shocks affect the regions differently. The scenarios modelling includes the regional modelling block that uses sectoral data and regional structure according to NUTS 3 for six regions and computes the results using bottom-up approach. The modelling results claim that the drastic demand fall for the air transport by 90% has a larger impact on the economic performance in the capital city (Riga) and near municipalities. Table 4 is a summary of regional economic effect caused by the scenarios. The data provide convincing evidence that dramatic economic shocks have larger impact both positive and negative on Riga region and Pieriga region, and relatively lesser impact on Kurzeme, Vidzeme, Zemgale, and Latgale region.

The results provide convincing evidence that urban areas are the most affected if as dramatic shocks as modelled take place (Table 5). In the case of the first scenario, when air transport demand falls by 90% the economic activity in the predominantly urban regions falls by 1.3% (when national-level decline is by 1.1%); meanwhile, the economy in predominantly rural regions shrinks only by 0.9%. The results of the second scenario of postal and courier services are consistent with previous results showing that predominantly urban regions are exposed more to economic shocks.

The general picture emerging from the analysis and modelling is that the urban regions due to higher economic activity and larger service sector are more affected to shocks both negative and positive that transport sector encounters. The rural areas are relatively less negatively affected during the crisis,

but at the same time, during economic recovery or some short-term economic boom (for example, in the post-COVID era) may lead to weaker and slower economic activity and the lagging behind urban areas will remain.

Conclusions

Government policy and safety measures in transport sector caused by COVID-19 have notable impact on economies. Economic modelling is a power tool to estimate the impact of certain shocks and evaluate the impact on other industries, regional development, and development, for example, in rural areas, etc. The research applies input-output model with additional regional modelling block using bottom-up approach. In the research two scenarios were elaborated – the first scenario that reflects the most dramatic negative shock in transport sector regarding air transport, and the second scenario that reflects the most positive side-effect or shock in transport sector regarding postal and courier services that face unexpected demand increase due to face-to-face shopping limitations and online shopping booming that demands delivery.

The findings demonstrate that service industries are more affected by both collapse in air transport (first scenario) and booming postal and courier services (second scenario), agriculture, manufacturing and energy sector are significantly less affected.

The results of regional modelling according to NUTS 3 level argue that the capital city region (Riga region) and suburbs (Pierīga region) are affected more than other regions in both modelling scenarios. The findings confirm that the urban areas due to higher economic activity and larger service sector are more affected to shocks both negative and positive that transport sector encounters. The rural areas are relatively less negatively affected during the crisis, but at the same time, during the economic recovery or some short-term economic boom (for example, in the post-COVID era) it may lead to weaker economic activity and the rural areas will continue to lag behind urban areas. This is an issue that the regional policy and economic policy makers are encouraged to take into account in order to ensure a more balanced regional economic development.

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CHANGES IN THE ECONOMY AS A SYSTEM: ENTREPRENEURSHIP UNDER THE INFLUENCE OF COVID-19

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Abstract

This research paper summarises the results of the rapid changes in the structure of the economic system as a result of the impact of the Covid-19 pandemic in 2020.

The following tasks were set for the research: to describe the national economic system before COVID-19 pandemic in Latvia, to identify and assess the main features of changes in the national economic system during 2020 and to identify and assess the geographical location of structural changes in the country.

The obtained results indicate three main tendencies in the structure of the economic system. Some economic segments indicate that the number of employees has increased in the time of the pandemic influence, some almost remained unchanged or experienced a decrease. As the linear changes in the volume of employees in the elements of the main structure of the economy take place to a different extent, then there is also an increase or decrease in the share of certain main segments in the regions of Latvia.

Key words: COVID-19, economic system, employment rate, regional economics, structural changes.

JEL code/ classification: P27; R12

Introduction

Any development identifies itself as a process of growth and change, characterised by a number of important differences. One of the most important differences is that if all components of the system develop evenly, the linear growth of the entire system is also pronounced. On the other hand, if the components of the system have different growth rates, structural changes develop. This fully applies to the economy of any country as an economic system. It is important that the increase in the share of one of the components of this economic system – the national economy- is related to the content and organisational development of innovative activities (Ogoko, 2016; OECD, 2015; European Commission, 2021).

The economy as a system of understanding and the process of changing this system has become an essential problem for scientific and political analysis. The combination of different elements is not a system. It becomes a system only when the elements that make up this system interact and changes in each individual element have a greater or lesser effect on other elements of the system and thus bring changes in the structure of the economic system by changing the positions of individual elements (Askoff, 2018; Tulonen, 2018). Influenced by this aspect, the Fourth Industrial Revolution is widely discussed at the beginning of the 21st century as an important component of the changes ranking place in humanity as a whole (Schwab, 2016; Bachtler *et al.*, 2019).

Over time, the study of the economy as a system has become the object of research in several regions of the world, such as the European Union (EU), Latin America and the Caribbean, as well as in individual counties such as Japan, Russia and, obviously, also Latvia research object (OECD, 2015; Nishi,

2015; Mironov & Konovalova, 2019; Mihņenoka & Šenfelde, 2017; Rivza, Kruzmetra, & Jeroscenkova, 2019; Rivza, Kruzmetra, & Rivza, 2020).

If authors' previous studies covered the processes of change over a longer period of time, this paper summarises the results of the rapid changes in these processes as a result of the impact of the COVID-19 pandemic in 2020, which can be formulated as the object of the current study.

The following research tasks were set in the research process: 1) to characterise the national economic system development tendencies before COVID-19 pandemic in Latvia, 2) to identify and assess the main features of changes in the national economic system during 2020, 3) to identify and assess the geographical location of structural changes in the country.

Materials and Methods

For theoretical framework of the research, relevant scientific research papers, using monographic synthesis and analysis methods have been used. For the analysis, the statistical data and information sources from the European Innovation Scoreboard (European Commission, 2020), Eurostat classification of industries (European Commission, 2008), and Central Statistical Bureau of Latvia (CBS) including data on changes in the national economy in the period 2010 – 2018 and in-depth on changes during 2020 were taken.

Obtained data were processed by descriptive statistical analysis methods, as well as the grouping method, based on important indicators as to the number of employees in the respective economic segment. The information obtained during the grouping also opens the possibility to identify linear and structural changes

in the economic situation in the country as a whole and in the planning regions of the country.

Results and Discussions

As noted in European Innovation Scoreboard, Latvia is included in the group of EU countries as a moderate innovator that is characterised by rapid growth and, consequently, in terms of economic indicators, is approaching the average level of development of the EU countries. If the average performance change EU between 2012 and 2019 improved by 8.9 percentage points, then for five Member States the performance improved by 20 percentage points or more. Latvia is included in 20 percentage points (%-points), showing the most pronounced growth increase with an indicator 23.3%-points. This positive result is provided ‘Total Entrepreneurial Activity... and Enterprise births’ (European Commission, 2020).

National economic system before the COVID-19 pandemic

According to the latest data, which characterise the structure of the economic system in a year, such a view is formed regarding main trends of changes in the period from 2010 until and including 2018 (Figure 1).

During the calculations, the obtained data confirm both the increase in the number of employees and the increase of net turnover of the companies as a result

of economic activity. More important results are that show the predominance of net turnover growth over employment growth. Exactly these results most clearly present the changes taking place in the economic system. Growth of occupied jobs and net turnover of enterprises in comparison to the analysed period leads to conclusions that three options for change are possible. First – as the number of employees increases, the net turnover of the respective economic segment also increases. Second – as the number of employees decreases, the net turnover of the respective economic segment can also decrease. The third option is when the number of employees decreases, but at the same time the significant increase in net turnover of the national economic activities is observed. An example is the Financial and Insurance activities segment (K), wherein in the period covered by the study, i.e., 2018 compared to 2010, the number of employees decreases to 87.4%, but the net turnover of the national economic activities has a significant increase – 242.0%. Lest to analyse the structural changes in the economic system, it is necessary to pay attention to the fact that structural changes are taken not only in the economy as a whole system, but also within its segments (Rivza, Kruzmetra, & Jeroscenkova, 2019). A considered example is the changes in the internal structure of the Information and Communication

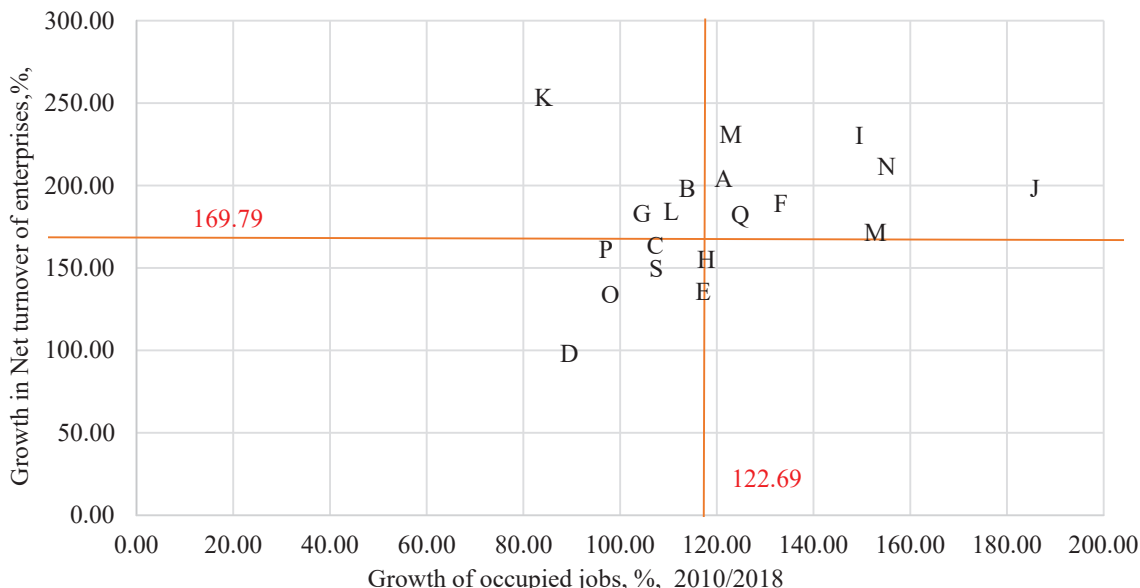


Figure 1. Changes in the Latvian economic system during 2010–2018.

A – Agriculture, forestry and fishing; B – Mining and quarrying; C – Manufacturing; D – Electricity, gas, steam and air conditioning supply; E – Water supply, sewerage, waste management and remediation activities; F – Construction; G – Wholesale and retail trade; repair of motor vehicles and motorcycles; H – Transportation and storage; I – Accommodation and food service activities; J – Information and communication; K – Financial and insurance activities; L – Real estate activities; M – Professional, scientific and technical activities; N – Administrative and support service activities; O – Public administration and defence; compulsory social security; P – Education; Q – Human health and social work activities; R – Arts, entertainment and recreation; S – Other service activities (European Commission, 2008).

Source: Authors’ compiled based on Central Statistical Bureau of Latvia 2020 data.

Table 1

Changes in the structure of Latvia's economic segments in 2020 until the end of the 3rd quarter

Calculation of changes in the number of employees: 100.0% in the 4 th quarter of 2019, but 98.6% in the 3 rd quarter of 2020		
Groups	Number of segments	Economic activities segments included in a group indicated in %
Group 1 – Increase in the number of employees - over 100.0%	7	A-107.2, B-135.0, F-100.8, J-100.3, O-101.2, P-100.7, Q-102.8
Group 2 – Insignificant reduction – less than average	1	C-99.2
Group 3 – The reduction is higher than average	11	D-94.9, E-97.3, G-98.0, H-93.0, I-86.6, K-96.5, L-97.9, M-94.9, N-96.5, R-93.0, S-94.6

A – Agriculture, forestry and fishing; B – Mining and quarrying; C – Manufacturing; D – Electricity, gas, steam and air conditioning supply; E – Water supply, sewerage, waste management and remediation activities; F – Construction; G – Wholesale and retail trade; repair of motor vehicles and motorcycles; H – Transportation and storage; I – Accommodation and food service activities; J – Information and communication; K – Financial and insurance activities; L – Real estate activities; M – Professional, scientific and technical activities; N – Administrative and support service activities; O – Public administration and defence; compulsory social security; P – Education; Q – Human health and social work activities; R – Arts, entertainment and recreation; S – Other service activities.

Source: Authors' calculations based on Central Statistical Bureau of Latvia.

services group (J) segment based on the results of calculations.

Within a segment of economic structure, differences may arise between the components with segment. In general, if the growth of the segment's net turnover lags behind the growth of the number of employees, then certain components or subsegments of this segment show a significant increase in productivity and innovative productivity of employees in this segment – Computer programming, consultancy and related activities (J62) net turnover growth – 359.6% and Information service activities (J63) net turnover increase up to 413.8%.

The main features of the changes that occurred in 2020 in the national economic system

In 2020, the Covid-19 pandemic has undoubtedly had an impact not only public health but also on the economy as an important area of public welfare. One of the most important indicators of change is the change in the number of employees. It is also extensively used in European Innovation scoreboard calculations (European Commission, 2020). Using the calculated data on employment in the segments of the economic system at the end of the 3rd Quarter of 2020, the following view has been formed on the changes that have taken place as a result of the impact of the Covid-19 pandemic. There are segments in which, despite the difficult pandemic situation, an increase in the number of employees can be observed, reaching its maximum in Mining and quarrying segment (B – 135.0%). At the same time, economic segments with the maximum decrease in the number of employees also stand out, where the Arts, entertainment, and

recreation segment (R – 93.0%) suffers the greatest losses, and even more so the Accommodation and food service activities segment (I – 86.6%), which are closely related to the restrictions introduced in Latvia in order to reduce the spread of Covid-19. If the reduction of the number of employees in each segment of the economic system in comparison with the average indicator for the analysis is selected as a criterion for data analysis, three variations of changes are formed, where economic activities segments were compiled in groups. Group 1 – the number of employees at the end of the 3rd quarter of 2020 exceeds the number of employees at the end of the 4th quarter of 2019, which is assumed by 100.0% in this segment. Group 2 – the reduction in the number of employees is minimal, i.e., less than the average reduction. Group 3 – the reduction in the number of employees is higher than average and reveals the economic system is most affected by the pandemic (Table 1).

The impact of the Covid-19 pandemic is manifested not only in the economic system as a whole, slowing down the activity of one or the other segment, but in a differentiated way affecting the internal structure of the segment, i.e. subsegments. If the number of employees in Manufacturing as a whole has decreased by 1.8%-points compared to the situation at the end of the 4th quarter of 2019, then in some sectors of this segment this change is different: if the number of employees in Manufacture of basic metals (C24) has increased to 108.4% in the three quarters of 2020, then in Manufacture of coke and refined petroleum products (C19) it has decreased to 36.5%. This fact once again confirms that the economic system must be analysed

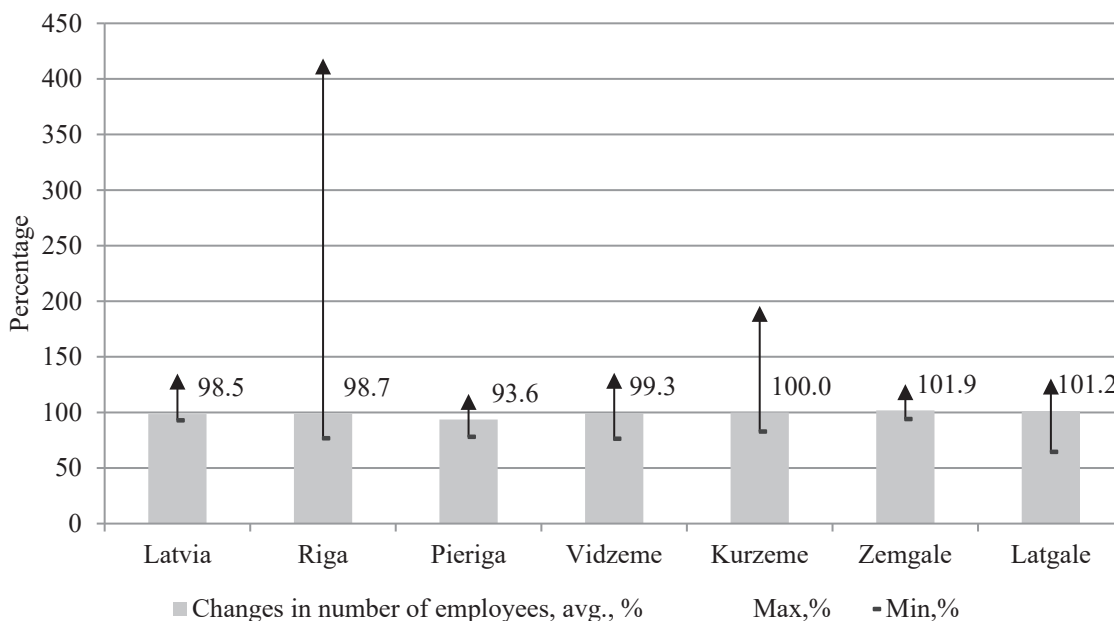


Figure 2. Changes in the structure of economic segments in regions of Latvia in 2020 until the end of the 3rd quarter.

Source: Authors' compiled based on Central Statistical Bureau of Latvia data.

not only from the point of view of the main economic segments, but also analyse the internal structural changes of the most important segments, such as Agriculture, forestry and fishing (A), Manufacturing (C), Information and communication (J), and Financial and insurance activities (K). The results obtained during the analysis logically raise the question – are the variations of these employment changes determined only by the Covid-19 pandemic and the restrictions on the movement and concentrations of people introduced during it? Or, no less, but even more, the shortcomings of the system of support of economic activity developed by governments? The analyses of the economic activity support system implemented by governments is a topical scientific research task. And the activity can begin to develop, obtaining a sufficient amount of content of information on all developments in the economic system and its structural changes.

Geographical location of structural changes in the economy as a system in Latvia

The Aggregate performance indicators (API) of any country provide an opportunity to assess the positions of a represented country outside the borders, for example, Latvia in the EU or in the group of Baltic States. Changes in the economic system as a whole and the structures included in it, can be viewed not only by sectors or segments, but also in a spatial or geographical breakdown. These are economic activity planning regions and Latvia is statistically indicated into the following six regions: Riga, Pieriga, Vidzeme, Kurzeme, Zemgale and Latgale

regions. As the Covid-19 pandemic covers the entire territory of the Latvia, it was decided to analyse not only structural changes in the economic system but also geographical breakdown – each statistical region separately, performing the framework of research work. Consequently, the research aim expanded, not only to identify changes in the structure of the economic system by planning regions but to compare the course of these processes within the state and to determine whether common and different features are observed (Figure 2).

The calculated percentage changes show that the economic system of each planning region of Latvia has undergone linear changes in separate segments – results in segments are different, each showing different tendencies – some segments indicate that the number of employees had increased, some almost remained unchanged or experienced a smaller or larger decrease. As the linear changes in the volume of employees in the elements of the main structure of the economy take place to a different extent, then, of course, there is also an increase or decrease in the share or certain main segments in the region. Finding such changes, the question arises – in which basic segments of the economy by regional breakdown, there is an increase in employment and where the indicators indicate a decrease. Analysing the economic segments by groups, according to changes in the number of employees (Table 1), quite different tendencies emerge in the economic systems by the planning regions of Latvia (Figure 3).

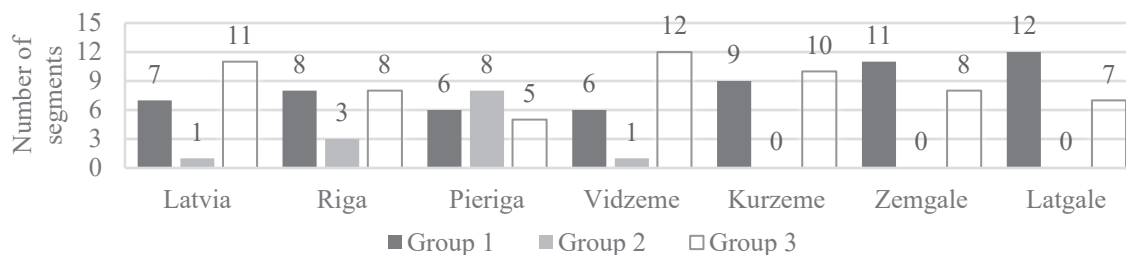


Figure 3. Changes in the number of employees in the planning regions of Latvia in the main segments of economy

Group 1 – Increase in the number of employees – over 100.0%; Group 2 – Insignificant reduction – less than average; Group 3 – The reduction is higher than average.

Source: Authors' calculations based on Central Statistical Bureau of Latvia data and according to the grouping obtained in Table 1.

The number of economic segments by groups is different when compared between all planning regions of Latvia. In Latgale and Zemgale regions, the number of basic segments in economy, in which the number of employees increased dominates, while Vidzeme and Kurzeme regions indicated the decrease of number of employees. In Riga region, there are

equivalent changes in the groups, which indicate an increase and decrease of the number of employees in basic segments of economy. Optimal indicators have been determined in the Pieriga region, as showing a smaller number of basic segments, where the number of employees is significantly decreasing. In the Pieriga planning region, the basic segments

Table 2

Comparison of structural changes of Zemgale and Vidzeme regions economic system

Calculation of changes in the number of employees: in the 4 th quarter of 2019 is 100.0%, but in the 3 rd quarter of 2020 is 98.6%				
Groups	Number of segments	Economic activities segments included in group indicated in %	Number of segments	Economic activities segments included in group indicated in %
		Zemgale region		Vidzeme region
Group 1 – Increase in the number of employees - over 100.0%	11	A-117.4, B-114.1, C-102.4, D-101.0, F-103.5, I-125.5, J-101.3, L-102.9, M-105.7, O-101.7, S-104.5	6	A-112.2, B-135.7, E-125.7, I-113.0, M-133.7, Q-101.4
Group 2 – Insignificant reduction – less than average	0	-	1	O-99.9
Group 3 – The reduction is higher than average	8	E-94.0, G-99.5, H-98.4, K-94.8, N-95.2, P-97.8, Q-97.8, R-97.6	12	C-97.0, D-79.6, F-94.2, G-99.0, H-97.2, J-93.4, K-76.3, L-97.2, N-80.4, P-96.4, R-95.8, S-78.1

A – Agriculture, forestry and fishing; B – Mining and quarrying; C – Manufacturing; D – Electricity, gas, steam and air conditioning supply; E – Water supply, sewerage, waste management and remediation activities; F – Construction; G – Wholesale and retail trade; repair of motor vehicles and motorcycles; H – Transportation and storage; I – Accommodation and food service activities; J – Information and communication; K – Financial and insurance activities; L – Real estate activities; M – Professional, scientific and technical activities; N – Administrative and support service activities; O – Public administration and defence; compulsory social security; P – Education; Q – Human health and social work activities; R – Arts, entertainment and recreation; S – Other service activities.

Source: Authors' calculations based on Central Statistical Bureau of Latvia data.

have a marked minimum reduction in the number of employees.

For a further analysis, Latgale and Zemgale regions data to analyse the changes in economic system in conditions of Covid-19 pandemic have been selected. Thus, a broader explanation of changes taking place in the regional economic system is obtained (Table 2).

A comparison of the processes shows that:

- In four segments (A, B, I and M) there is an increase in the number of employees in both regions;
- In six segments (G, H, K, N, P and R) there is a reduction in the number of employees in both regions;
- In nine segments (C, D, E, F, J, L, O, Q and S) comparing the regions are opposite changes, i.e., in Vidzeme region the number of employees in 2 segments (E and Q) is increasing, but in Zemgale region it is decreasing, while in Zemgale region, the number of employees in 7 segments (C, D, F, J, L, O and S) is increasing, but in Vidzeme region is decreasing.

The national framework regulations to mitigate the effects of the Covid-19 pandemic apply to all the national economy including all parts of it. Therefore, it is not clear what affects the differences within the same economic segment in each of the country's region. It is unclear if subjective circumstances, such as people's readiness to adapt to ongoing changes in economy and the competence of governance structures in the regions play a leading role. However, it is clear that solutions to existing issues can be found in further research.

If the results of the research process are accepted as sufficiently significant, it is possible that the national business support system for the maintenance and successful promotion of economic activities should also include a specific aid regulation from a regional perspective.

Conclusions

In accordance with the set tasks, the data analysis leads to the following conclusions:

1) The national economic system development tendencies before COVID-19 pandemic in Latvia have shown quite a significant growth. Digitization-related industries are particularly prominent. The highest growth rates in terms of employment are shown by economic segments such as Information and communication (J) – 189.0%; Administrative and support service activities (N) – 156.3%; Professional, scientific and technical activities (M) – 156.1%; Accommodation and food service activities (I) – 151.9%. But if we compare the increase in net turnover of the companies, the highest growth rates are in economic segments such as Financial and insurance

activities (K) – 242.0%; Arts, entertainment and recreation (R) – 218.5%; Accommodation and food service activities (I) – 218.1%; Administrative and support service activities (N) – 196.7%. Although the growth rate between indicators is different, it should be emphasised that more important results are those that show the predominance of net turnover growth over employment growth.

2) The COVID-19 pandemic has affected each state's economy, including Latvia, bringing changes to the economy the main features of changes in the national economic system during 2020. The case of Latvia shows that during the last year several restrictions were implemented, with the aim to reduce the rapid spread of infection, but as a result of these restrictions, in several sectors economically active companies were led to the suspension. One of the main consequences of economic activity suspension is a reduction of the number of employees in specific sectors. According to the results of the study, changes in the number of employees, comparing the results of the 4th quarter of 2019 (assuming by 100.0%) to the 3rd quarter of 2020 were analysed, and it can be concluded that the most affected sectors are related to the provision of services, such as Accommodation and food service activities segment (I) – 86.6%, which is directly related to the restrictions affecting the tourism sector, as well as Transportation and storage segment (H) – 93.0% and Arts, entertainment and recreation (R) – 93.0%. In total, 11 of 19 economic segments showed a decrease in the number of employees, indicating that solutions and support mechanisms need to be found to improve results of employment. To get a clearer understanding of the whole economic system, it must be analysed not only from the point of view of the main economic segments but also to analyse the internal structural changes of the most meaningful segments of the country.

In order to maintain the possibility to hold an economic activity in existing conditions, it is necessary to reorient economic activity, seeking solutions for successful further development. Although various financial support mechanisms are being developed and offered to Latvian suffered entrepreneurs from the COVID-19 pandemic influence, a more important role should be given to support that would encourage entrepreneurs to look more broadly and try to adapt their economic activities to the current situation. As one of the tools would be to promote good practice, through the media or other public information tools, showing suffered entrepreneurs the possible solutions that could be implemented to sustain economic activity. The innovative approach and adaptability in some cases can be the key to problem-solving.

3) Data analysis makes it possible to identify the geographical location of structural changes in the

country, which shows that the processes of change caused by the pandemic are not the same in the regions of the country. Results indicate that the economic system of each region of Latvia has undergone linear changes in separate segments and results in segments showing different tendencies. In Latgale and Zemgale regions more basic segments indicate an increase in the number of employees, while Vidzeme and Kurzeme regions number of employees is decreasing. Comparing data of Latgale and Zemgale regions, it was more important to discover those nine segments that show opposite changes. In the Vidzeme region, an increase in the number of employees is identified at segments Water supply, sewerage, waste management and remediation activities (E) – 125.7% and Human health and social work activities (Q) – 101.4%, while in the Zemgale region, the decrease E – 94.0% and Q – 97.8% is observed.

In order to better assess the changes brought about by the pandemic, a longer period of time is needed,

which will provide more and detailed information on the changes caused. Particular attention should be paid to the growth of exports and sale markets in the country in order to be able to make proposals for the development of the strategy for the further development of the country's economic system. Policy-makers need to base their decisions on the research of structural changes in the national economy, targeting the support mechanisms in future for those, who can try to adapt to existing constraints. The authors consider that research on structural change in the economic system needs to be done more precisely, analysing the structural changes at the subsegments level.

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ORGANIC PRODUCTION AS PART OF A SUSTAINABLE LOCAL FOOD SUPPLY CHAIN



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Abstract

Organic farming is a sustainable food production system that involves best environmental practices, a high level of biodiversity protection, conservation of natural resources, high animal welfare standards and production according to the desires of a certain group of consumers to consume foods produced by using natural products and processes. The research aims to assess the availability of organic food in the local food supply chain. The research found that the production of organic food is driven by the growing consumer interest in healthy and high-quality food. Consumers prefer short food supply chains to buy organic food from local producers. The range of available organic foods is affected by various micro and macro environmental factors every year. An analysis of organic foods by degree of processing revealed that there were available mostly unprocessed foods (fresh fruit and vegetables) or minimally/basically processed foods (milk, dairy products, pastries); therefore, the products have low levels of saturated sugars, salt and trans fats.

Key words: organic production, sustainability, local food supply chain.

Introduction

The world's population is not only growing but also changing and urbanizing, and the population's demands and nutritional needs are evolving. The demand for food in urban areas plays an increasing role in determining what foods to grow and how to process, distribute and market the foods. Economic growth, climate change and global trade, however, are changing the way food is produced, processed and sold (Satterthwaite *et al.*, 2010). Agriculture and food production systems affect food availability and profitability (FAO, 2016) as well as food quality and diversity (IBRD/World Bank, 2007; HLPE, 2016, 2017).

Organic farming is a comprehensive system of farm management and food production that involves best environmental practices, a high level of protection of biodiversity, conservation of natural resources, high animal welfare standards and production according to the desires of a certain group of consumers to consume foods produced by using natural products and processes. The organic production method thus plays a dual societal role, where it on the one hand provides for a specific market responding to a consumer demand for organic products, and on the other hand delivers public goods contributing to the protection of the environment and animal welfare, as well as to rural development.

The research aims to assess the availability of organic food in the local food supply chain.

Materials and Methods

The research used assessments by various research paper authors for the theoretical framework and discussion on sustainable local food supply chains. Trends in the market of organic agricultural products in Latvia in the period 2015–2019 were analysed

using the database of the Agricultural Data Centre (ADC) (statistical data on organic farming) and the information available from the Food and Veterinary Service. Research methods employed: monographic, analysis and synthesis, statistical analysis and logical construction.

Results and Discussion

A food supply chain consists of activities and actors that transport food from the place of production to the place of consumption, including waste disposal (Hawkes & Ruel, 2012). The stages of a food supply chain include: production; storage and distribution; processing and packaging; and sale (Figure 1). At each stage, a number of actors, both public and private, who are affected by environmental, economic, political and other factors are involved (Porter & Millar, 1985). The decisions taken by the actors at each stage of a food supply chain affect the ways food is processed and produced, as well as the food environment.

In Latvia, the demand for organically grown and produced food constantly increases, and the organic farming industry and market continues developing. In the period from 2015 to 2019, the organically certified agricultural land areas in Latvia increased by 52.19 thou. ha or 2.9%, reaching 289.8 thou. ha or 14.5% of the total agricultural area. Organic farming is characterized by multi-industrial production. Grains (mostly oats, buckwheat) and potatoes accounted for the largest proportion in total crop output. Over a five-year period, the quantity of grains produced increased on average by 18.2%, while the quantity of potatoes increased by 7.0% (Table 1).

The output of organic industrial crops (turnip rape, oilseed rape, medicinal plants) significantly increased in Latvia. Over a five-year period, it increased on average by 46.8%, reaching a total of 1482.6 tons

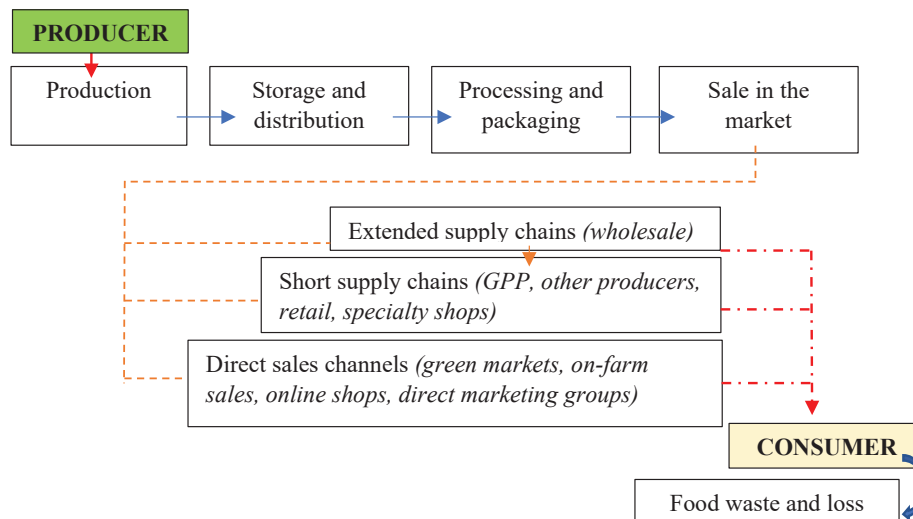


Figure 1. Model of a local food supply chain.

Source: authors' construction.

in 2019. Positive trends could be observed in the vegetable and fruit industry, as the output increased, on average by 16% and 18.5%, respectively, over a five-year period. According to ADC data, the most significant crops produced by farmers were cabbage,

pumpkin, carrot, beet and cucumber. Over a five-year period, the output of cucumber (47.4%) and pumpkin (31.6%) increased at the fastest rates, while cabbage production decreased by 3.5%, yet this crop is still considered to be sufficiently significant among the

Table 1

Output of organic agricultural products in Latvia in 2015–2019, tons

Products	2015	2016	2017	2018	2019	Average change rate, %
Grain	60202.5	61687.2	71058.6	74356.4	111994.6	18.2
Industrial crops	356.4	694.7	1086.1	1098.0	1482.6	46.8
Vegetables, incl.:	1842.0	2354.9	2057.6	2159.8	3106.5	16.0
<i>Cabbage</i>	269.1	255.8	271.6	250.7	231.8	-3.5
<i>Pumpkin</i>	379.7	648.3	382.0	555.7	840.0	31.6
<i>Carrot</i>	319.0	477.3	419.2	320.4	330.7	4.3
<i>Beet</i>	188.2	210.8	248.3	212.2	273.8	11.1
<i>Cucumber</i>	93.7	152.8	110.2	114.1	286.2	47.4
Potato	18405.5	16259.4	15130.1	20410.7	22808.4	7.0
Fruits and berries, incl.:	1528.7	2189.7	1945.8	2985.1	2641.8	18.5
<i>Apples</i>	8986.0	1446.6	1290.5	2030.2	1796.4	24.0
Beef	3725.1	2110.5	2165.6	2559.2	2164.3	-9.5
Mutton and goat meat	329.3	201.5	272.3	257.6	285.8	0.5
Pork	119.0	49.1	80.4	63.4	61.5	-4.8
Meat of other animals	13.4	4.8	17.1	25.4	16.0	-9.3
Cow milk	66769.0	72105.0	80016.0	77235.0	83386.0	5.9
Goat milk	243.0	258.0	381.0	349.0	346.0	11.2
Honey	291.1	273.4	343.7	409.5	359.3	6.6
Chicken eggs (thou. pieces)	809.8	1040.7	1427.1	1649.9	2481.5	32.9

Source: authors' calculations based on ADC data.

Table 2

Output, sales and self-consumption of organic products in Latvia in 2015 and 2019, thou. Tons

Primary products	2015			2019			Average change rate, % – tm(b)
	Output	Sales	Self-consumption	Output	Sales	Self-consumption	
Grain	60.20	31.62	28.58	111.99	74.72	37.27	136.31
Industrial crops	0.36	0.17	0.19	1.48	1.35	0.14	692.70
Vegetables, incl.:	1.84	0.67	1.18	3.11	0.97	2.14	45.69
<i>Cabbage</i>	0.27	0.07	0.20	0.23	0.06	0.17	-18.34
<i>Pumpkin</i>	0.38	0.10	0.28	0.84	0.27	0.57	183.12
<i>Carrot</i>	0.32	0.10	0.22	0.33	0.10	0.23	-1.25
<i>Beet</i>	0.19	0.09	0.10	0.27	0.07	0.21	-23.71
<i>Cucumber</i>	0.09	0.06	0.04	0.29	0.06	0.22	10.69
Potato	18.41	4.69	13.72	22.81	10.48	12.33	123.37
Fruits and berries, incl.:	1.53	0.91	0.62	2.64	1.34	1.30	47.04
<i>Apples</i>	0.90	0.48	0.42	1.80	0.79	1.01	63.83
Beef	3.73	2.85	0.87	2.16	1.88	0.29	-34.22
Mutton and goat meat	0.33	0.28	0.05	0.29	0.19	0.10	-33.16
Pork	0.12	0.06	0.06	0.06	0.01	0.05	-78.28
Meat of other animals	0.013	0.004	0.010	0.017	0.005	0.01	20.61
Cow milk	66.77	56.4	10.23	83.39	72.25	11.14	27.78
Goat milk	0.24	0.15	0.10	0.35	0.22	0.12	53.54
Honey	0.29	0.25	0.04	0.36	0.22	0.14	-11.55
Chicken eggs (thou. pieces)	0.81	0.53	0.28	2.48	1.47	1.01	178.07

Source: authors' calculations based on ADC data.

vegetables produced. In the fruit and berry category, apples made up the largest proportion. Over a five-year period, apple production increased on average by 24%.

In the livestock industry, cow milk represents a significant proportion in total livestock output. Over a five-year period, the output of cow milk increased on average by 5.9%, totalling 83386 tons in 2019. Although the area under grazing livestock production represented a significant proportion in the total utilized agricultural area, beef, pork, poultry as well as wild animal meat production decreased over a five-year period. This was due to a number of factors: low meat market prices, lack of meat processing facilities and an increase in exports of live animals. The pig industry was significantly affected by the spread of African swine fever (ASF) on farms. Another important obstacle was the problem of purchasing breeding livestock. It is positive that in recent years poultry production, particularly egg production, increased significantly. This was due to the fact that in recent years consumers paid more attention to eggs produced under a free-range system, which led to an increase in the production of organic chicken eggs by 32.9% over a five-year period.

According to the Common Agricultural Policy factsheet, Latvia is characterized by a large number of self-consumption farms (Factsheet on ..., 2015). An assessment of the situation in organic farming is presented in Table 2. The assessment was based on a case study.

In 2015, market-oriented products were cereals, beef, mutton and goat meat, pork, raw milk, honey and chicken eggs. The sales of the products as a percentage of total production exceeded 50%, while the other products: industrial crops, potato, fruits and berries, vegetables, poultry and wild animal meat were mostly used for self-consumption. In 2019 compared with 2015, the sales of industrial crops and fruits and berries (mostly apples) significantly increased owing to an increase in their output. However, due to a considerable decrease in the number of pigs in recent years, the farmers started producing pork mainly for self-consumption, in contrast to 2015 when 50% of the pork produced was sold. As regards honey in relation to changes in the certification requirements for organic beekeeping that have been in force since 2018 (bees must be placed no closer than 3 km from fields where pesticides are applied), it is expected that the

amount of organically certified honey will continue to decrease. Overall, it could be concluded that farmers use on average 30% of the total production for self-consumption, incl. also for animal feed.

Food processing and packaging contribute to *food safety and nutritional value* through *preventing food quality loss and waste* and extending the shelf life, increasing nutrient bioavailability and improving food sensory and functional properties and killing food microbes and toxins (van Boekel *et al.*, 2010; Weaver *et al.*, 2014; Augustin *et al.*, 2016). The most common kinds of food processing are grinding, cooling or freezing, smoking, heating, canning, fermentation and extrusion cooking (Augustin *et al.*, 2016).

Over the last five years, the number of companies and farms engaged in the pre-processing and processing of organic products increased from 227 to 351. Despite the positive trend, more than half of the processors were farm-based (65.35%) and some of them had the status of home producer (more than 37.61% of the total processors), which significantly limited their opportunities to retail their products (Table 3).

Over a 5-year period, the number of processors increased by 11.52%. The numbers of processors broken down by product category were variable in the period 2015–2019. In the period of analysis, most processors were engaged in processing fruits, berries, vegetables and potato. Over the five-year period, the number of processors in this product category increased by 9.49%, yet the increase was mostly due to an increase in the number of farm-based processors; therefore, the quantities processed were small. In 2019, on average, only 30.88 t of agricultural raw materials were processed per processor.

A relatively large proportion of processors belonged to the category “other food products”, which included the production of tea, spices and additives, as well as sugar confectionery, the pre-processing, processing and packaging of honey and other beekeeping products. With regard to the production of tea from wild medicinal plants, on 21 April 2015 amendments were made to Cabinet Regulation No. 171, which stipulate that in order for a farmer to receive support for areas under wild medicinal plants, it is necessary to register the facility with the FVS plant for the pre-processing and further processing of medicinal plants. As a result, the number of processors increased in this category, which is logical regarding this product category because in order to remain competitive with relatively small production volumes, one of the ways is to specialize in the production of products from high-quality raw materials.

In the period from 2015 to 2019, the quantities of processed products increased significantly. Of the total output in 2015, 4.54% raw materials were processed, while in 2019 the proportion increased to 14.34%. The calculation did not include the output of eggs, seed, apiculture products (excluding honey) and wild plants (except those for tea production), as the products were not processed.

The degree of food processing can affect the amount of nutrients entering or leaving the food supply chain (van Boekel *et al.*, 2010). Highly processed foods have higher amounts of saturated fat, sugar, and sodium than less processed foods (Poti *et al.*, 2015; Monteiro *et al.*, 2013). Food processing can change the content and bioavailability of nutrients in the food (Augustin *et al.*, 2016) as well as improve the attractiveness and convenience of the food (Mozaffarian, 2016). However, food processing can

Table 3

Number of organic processors by product category in Latvia in the period 2015-2019

Product category	Number of processors					Average change rate, %
	2015	2016	2017	2018	2019	
Meat and meat products	16	22	27	34	24	14.19
Fruits, berries, vegetables and potato	60	67	69	76	86	9.49
Vegetable oils and animal fats	2	2	3	4	5	27.08
Milk and dairy products	24	24	22	24	30	6.44
Grain processing products and starch	11	12	13	13	13	4.36
Bread and pastry goods and cakes	13	17	19	18	20	12.10
Other food products	89	97	112	128	151	14.18
Feed	2	3	4	14	6	69.05
Beverages	10	12	12	5	16	45.42
Total	227	256	281	316	351	11.52

Source: authors' calculations based on the FVS database.

Table 4

Output of organic products by product category in Latvia in the period 2015-2019, t

Product category	Quantity, t					Change from base year, %	Quantity (t) per processor in 2019
	2015	2016	2017	2018	2019		
Meat and meat products	759.9	758.8	1362.0	1645.7	1553.1	104.38	64.71
Fruits, berries, vegetables and potato	611.9	803.4	852.1	1875.9	2655.9	334.04	30.88
Vegetable oils and animal fats	16.7	1.9	2.9	3.6	2.0	-88.02	0.4
Milk and dairy products	3004.2	3411.3	3992.9	3306.3	7380.4	145.67	246.0
Grain processing products and starch	1862.6	3619.3	7680.4	16767.2	23024.3	1136.14	1771.1
Bread and pastry goods and cakes	108.8	93.6	81.4	1161.4	1220.1	1021.42	61.0
Other food products	65.1	42.7	68.7	138.5	325.6	400.15	2.15
Feed	416.9	640.6	953.9	1299.8	1577.3	278.34	262.88
Beverages	289.9	414.2	160.7	1073.8	846.6	192.03	52.91
<i>Total quantity, t</i>	7136.0	9785.8	15155	27272.2	38585.3	x	x
<i>Quantity processed as % of total output</i>	4.54	5.83	7.85	13.30	14.34	x	x

Source: authors' calculations based on ADC data.

also reduce the nutritional value of the food, as fibre and essential nutrients are separated, which should then be reincorporated into the food (Mozaffarian, 2016) or ingredients that should usually be restricted for health reasons, including too much sodium and sugar and unhealthy fats, e.g. trans fat (Weaver *et al.*, 2014; Augustin *et al.*, 2016), need to be added.

Among all the product categories in the period from 2015 to 2019, the output of organic grain processing products and starch increased most – 1862 tons were produced in 2015, while in 2019 it increased to 23 024 tons (Table 4).

The increase was due to the fact that some large processors focused on the production of organic products (Dobeles Dzirnavnies – organic oat flake products, while Aloja Starkelsen – organic potato starch). There was an increase in output among the other categories of processed agricultural raw materials, except for vegetable oils and animal fats, the output of which in 2019 decreased by 88% compared with 2015. At the same time, after a steady increase in the output of milk and dairy products until 2018, there was a significant increase in output in 2019, reaching 7380 tons of finished products, which was more than twice

the quantity produced in 2018 (3306t). The increase in the output of processed food could be explained by the partial specialization of some large processors in organic products. In the opinion of the authors, the motivation of entrepreneurs for boosting organic food processing was caused by the growing interest of consumers in organic products, an opportunity to occupy free market niches and public activities, incl. EU strategies, particularly the EU Biodiversity Strategy for 2030, including the new “From Farm to Fork” strategy. The spread of COVID-19 and the change in consumers' eating and shopping habits also made impacts on the consumption of domestic products.

The packaging of products can influence a consumer's decision to buy or not to buy the product. For example, given that organic products often have a shorter shelf life because no artificial preservatives or other chemicals that prevent spoilage of the products are added, it is important that lower weight or smaller volume packs are available to consumers. This way, the buyer can consume all the food purchased at once and, when shopping again, buy new and fresh produce without worrying that the previously purchased product has already expired and should be discarded.

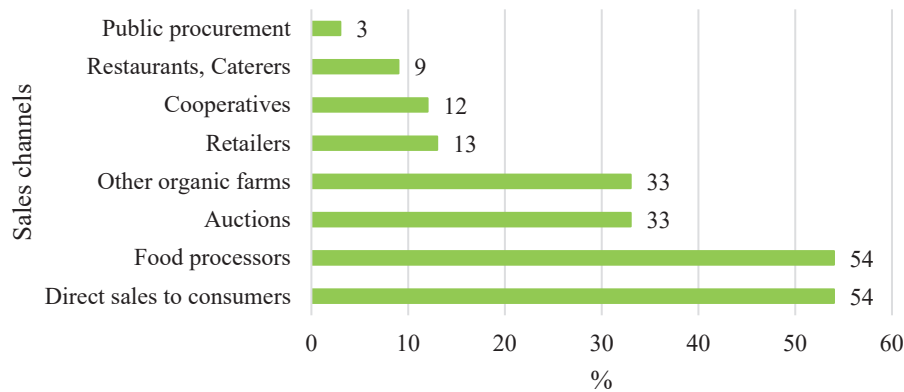


Figure 2. Most popular sales channels for organic products in Latvia.

Source: authors' construction based on Report on the effects ..., 2019.

Farmers use various channels for selling their products (Figure 3). The sales channels largely depend on the agricultural industry, the total output and the size of the land area farmed.

In most cases, farms that produce niche products, fruits and berries, vegetables, honey and chicken eggs sell their products directly to final consumers, and often the products represent a secondary source of income. Farms that manage over 30 ha of agricultural land already have a more pronounced specialization; moreover, as the area of agricultural land managed increases, the level of specialization also increases. Farms producing raw milk, beef and mutton, as well as starch potato and cereals mainly sell their products to processors. Often various kinds of feed (hay, haylage, silage, grain and legumes, potato, vegetables, milk, etc.) and breeding livestock are sold to other farms, depending on demand. In Latvia, sales of young beef cattle up to 300 kg or 7 months of age at auctions are popular. Farmers usually do not practise selling their products to retailers, as most of the products have a short shelf life, as well as the farmers have limited opportunities to regularly deliver a certain quantity of the products. As a result, only a fifth of farms use retail chains for sale. The proportion of sales through cooperatives in total sales is also low, only 12%, because the function of cooperatives is often performed by wholesalers and processors. A small number of farms sell their organic products to caterers and participate in public procurement. For organic farms, participation in green public procurement is hampered by the lowest price policy, delivery logistics, seasonality, paperwork, green procurement requirements for deliveries, the formal attitude of municipalities to organizing and managing a bid of tenders, as well as other factors. This trend could be viewed as negative, as it is caterers, and particularly budget institutions, e.g. schools, kindergartens, social care homes, hospitals, etc., that should set an

example of introducing a healthy diet into daily life through including as many organic foods as possible in the diet.

Conclusions

1. The output of organic products is affected by the growing consumer interest in healthy and high-quality food. Consumers prefer short food supply chains to buy organic produce from local producers.
2. Every year, the range of available organic products is affected by various micro and macro environmental factors: spread of various diseases (ASF, Avian influenza), weather conditions (droughts and rains), availability of production resources (seed, breeding livestock, etc.), various policy decisions on the availability of support, market prices, etc.
3. Over a five-year period, the output of beef, pork, poultry and wild animal meat decreased, while the production of chicken eggs and cow milk increased. In addition, farmers have started producing more fresh fruits and vegetables, as well as medicinal plants, oilseed rape and turnip rape.
4. In 2019 compared with 2015, main market-oriented products were cereals, beef, mutton and goat meat, raw milk, honey and chicken eggs. The sales of the products as a percentage of total production exceeded 50%, while other products: industrial crops, potato, fruits and berries, vegetables, poultry, wild animal meat and pork were mostly used for self-consumption.
5. The analysis of organic foods by degree of processing revealed that there were available mostly unprocessed foods (fresh fruit and vegetables) or minimally/basically processed foods (milk, dairy products, pastries); therefore, the products have low levels of saturated sugars, salt and trans fats.

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PROFITABLENESS AND PERSPECTIVE OF THE APICULTURE IN NORTH-EASTERN BULGARIA

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Abstract

The trends in the change of the profitability of Bulgarian beekeeping starting from the country’s accession to the European Union (EU) in 2007 to the present 2020, are being studied, depending on the changes in the market price of honey and its prime cost. The survey was conducted among selected apiaries in North-eastern Bulgaria. It has been found that they achieve a small net profit when selling conventional honey in the organizational markets – EUR 3.78 kg⁻¹. The realization of organic honey as a raw material in the organizational markets is not profitable for them. The apiaries have a net profit of EUR 7.98 kg⁻¹ for conventional and EUR 7.91 kg⁻¹ for organic honey, with distribution to a consumer market sale. The apiaries in Ruse district achieve 10.26% profitability of turnover in sales on conventional consumer markets, 8.83% in organic consumer markets and 8.2% in organizational conventional markets. Improving their profitability requires: 1) marketing strategies, through regional and cross-sectoral integration; 2) the production of royal jelly, pollen and propolis with high added value; 3) introduction of new technologies, increase in labour productivity, and 4) state subsidies to a hive for ecosystem pollination service.

Key words: beekeeping, cost, honey, conventional markets, organic markets, prime cost.

Introduction

Beekeeping in Bulgaria is the agriculture sector providing the largest alternative employment in depopulated rural areas. The favourable climatic conditions, the rich biodiversity of flowering vegetation and the possibility of funding under National and European programs are a prerequisite for its successful development. In 2019, the number of bee colonies increased by 10.8% compared to the previous year (Agrostatistics, 2020). The amount of honey produced in the country has increased by 14.5% compared to 2018. The average honey production per bee colony has decreased by 2.4% down to 16.4 kg. A decrease was also observed in the amount of sold honey, which is 4.0% less than in the previous period. Changes were also observed in the number of colonies per apiary, with a 23.9% increase in the share of apiaries with between 10 and 49 colonies and with 16.1% of those apiaries with between 50 and 149 colonies. These changes show the expansion of beekeeping production and the desire to turn it into a profitable business.

Despite the positive trends, beekeeping in Bulgaria faces a number of problems related to some changes such as: 1) beekeeping practice, 2) sources of nectar and pollen, 3) meteorological conditions, and 4) the realization of honey yield. The first three groups of changes directly affect the production of honey and pollen and indirectly the profitability of beekeeping production, while the changes related to the realization of honey yield directly affect the income and profitability of apiculture.

Furthermore, the role of bees as pollinators and their influence on agricultural production in Bulgaria is completely neglected. Best practices in beekeeping and pollination management help increase agricultural yield (Bradbear, 2009), (Kumar & Singh, 2003).

Placing beehives in agricultural land is crucial to optimizing the efficiency of bees in pollinating and harvesting honey bee products (Barnsley Beekeeper Association), (British Beekeepers Association, 2006), (Brosi, Armsworth, & Daily, 2008).

From 2019, beekeeping in Bulgaria is in a difficult situation by the European Commission decision to accept duty free import of honey from Argentina, Brazil, China, Ukraine and others. (Beekeepers, 2019). This has led to a significant reduction in the purchase price of honey and the profitability of beekeeping production. Trying to increase their incomes, many beekeepers increase the number of bee colonies. However, this requires many more investments, and due to the declining returns from beekeeping, it also leads to a decrease in its profitability. The profitability of the apiaries depends on the profit realized and the means by which it has been obtained. The return on equity is the ratio of net profit to total capital. When the apiaries make more profit with less capital, they will be more profitable. But without profit, the apiaries cannot achieve profitability, even if they invest considerable capital in beekeeping. The profit of each bee product depends on its income and costs. In order to determine the profit per unit of production, the income and expenses per unit of bee product – honey, wax, etc. – are required.

The aim of the study is to determine the profit from conventional and organic honey of farms in Northeastern Bulgaria in the last decade (2011–2019), by analyzing changes in market prices and cost.

Materials and Methods

The survey was conducted on the basis of data for changes in prices of honey for the period of 2011–2019, obtained from agro-statistic reports to the Ministry of Agriculture, Food and Forestry and information from

152 beekeepers for the period of 2011–2019, which keep records of their production costs and income of the products sold.

The data on the cost of honey in farms from north-eastern Bulgaria for the period 2011–2019 are based on a cluster sample of four nests from Rousse district – Nikolovo village, Brestovitsa village, Bazovets village and Yuper village. During the analysed period, as beekeepers, the authors conducted systematic observations in their own and neighbouring apiaries, exchanging information and experience about the cost of honey produced. Lyubenov observed 32 pcs conventional apiaries from the village of Nikolovo, Hristakov 42 pcs organic apiaries from the village of Brestovitsa and 44 pcs from the village of Bazovets, Atanasov 34 pcs conventional apiaries from the village of Yuper, i.e. a total of 86 pcs biological and 66 pcs conventional farms. The results were discussed with beekeeping unions and in the training of beekeepers in the National Agricultural Advisory Service.

The data on honey prices are from agrostatic governmental and market institutions – Ministry of Agriculture, Food and Forestry (www.mzh.government.bg), National Agricultural Advisory Service (www.naas.government.bg), Agro-market information system (<https://sapi.bg>). The sources of information about the cost of honey are apiaries in Ruse region and regional branch unions. The

methods used are retrospective analysis of prices and costs, monitoring and empirical study of the costs of regional apiaries and focus groups with representatives of industry unions. In Table 5 and 6, the cost of conventional and organic honey from Ruse region is systematized, synthesized and calculated.

Results and Discussion

In 2019, the North-eastern Region (Agrostatistics, 2020) had 190,417 colonies and was on the second place after North Central Region. The Ruse region is a part of the North-eastern region and is one of the average territories and population in Bulgaria – its area is about 3% and the population is about 2.5% of the national indicators (NSI, 2016). It is in the top 5 of the districts with the largest number of bee families in Bulgaria. The registered hives in the district are about 43,000. The Ruse region produces more than 1,000 tonnes of honey, which is about 10% of the national production, respectively and a similar part of the realized economic effect of pollination -50 million EUR year⁻¹ (Lyubenov, 2018). The average production of honey from a hive is close to and even above the national level due to the higher relative share of semi-professional and professional apiaries and favourable economic and geographical conditions. The income per unit of production of honey is dependent on its market price, which the beekeepers cannot influence.

Table 1

Changes in prices of honey 2011-2014, EUR kg⁻¹

Types of honey	Organizational market		Consumer Market	
	Conventional	Organic	Conventional	Organic
Acacia	3.58	5.11	6.14	7.16
Lime	3.07	3.58	5.11	6.14
Sunflower	2.56	-	4.09	-
Multiflora	2.30	3.32	3.58	4.60
Oilseed rape	2.05	-	3.07	-
Average	2.71	3.99	4.40	5.98

Table 2

Changes in prices of honey 2015-2017, EUR kg⁻¹

Types of honey	Organizational market		Consumer Market	
	Conventional	Organic	Conventional	Organic
Acacia	3.07	4.60	6.14	7.16
Lime	2.68	3.32	5.11	6.14
Sunflower	2.30	-	4.09	-
Multiflora	2.17	3.07	3.58	4.60
Oilseed rape	1.92	-	3.07	-
Average	2.45	3.68	4.40	5.98

Table 3

Changes in prices of honey 2018, EUR kg⁻¹

Types of honey	Organizational market		Consumer Market	
	Conventional	Organic	Conventional	Organic
Acacia	3.58	4.09	5.11	6.14
Lime	2.56	3.32	4.09	5.11
Sunflower	2.05	-	3.58	-
Multiflora	2.05	3.07	3.58	4.60
Oilseed rape	1.84	-	3.07	-
Average	2.40	3.48	3.89	5.27

Table 4

Changes in prices of honey 2019, EUR kg⁻¹

Types of honey	Organizational market		Consumer Market	
	Conventional	Organic	Conventional	Organic
Acacia	3.58	3.58	5.11	6.14
Lime	2.45	2.71	4.09	5.11
Sunflower	1.79	-	3.58	-
Multiflora	1.94	2.30	3.58	4.60
Oilseed rape	1.69	-	3.07	-
Average	2.30	2.86	3.86	5.27

In 2008–2009, the National Beekeeping Program (NBP) was launched in Bulgaria. At that time, honey prices were similar to prices in 2019. National markets for organic honey only developed after 2010, assuming that honey obtained from rapeseed and sunflower cannot be organic. Table 1, Table 2, Table 3, Table 4 outline the market prices in the national organizational and national consumer markets, with their organic and conventional segments. The prices on the national markets are the result of those on the international markets and the beekeepers cannot influence the prices. All markets and their segments have a steady downward trend in market prices for honey.

The cost per unit of production of honey in Ruse region depends on the labour input, and its cost is EUR 62.378 month⁻¹, social insurance, depreciation and costs for repair, nutrition, veterinary medicines, packaging, transport and more. The costs of selling of 1 kg honey are for unpackaging, packaging, transport and marketing. They all form the full unit cost of conventional and organic honey. In Table 5 and Table 6 the basic cost of conventional and organic honey is determined, under the established economic and geographical conditions of production in the region of Ruse. The cost may also be higher, depending on the distance between the apiary and the processing and packaging site, the prices of the factors and the means of production in investigated regions.

The comparison between the self-value costs of the most widely produced conventional and organic honey in the region of Ruse - the multiflora honey Table 5, Table 6 and its market prices Table 1, Table 2, Table 3 and Table 4 show that there are two negative trends for the analysed period. The first is that after Bulgaria's accession to the EU in 2007, there has been a steady increase in the prices and the means of production in Bulgarian agriculture, and thus the cost of agricultural production, including the beekeeping sector of the Ruse region.

The second trend is a steady decline in the prices of conventional and organic honey. At the beginning of the period prices were higher and the cost lower, but at the end of the period they were very close, causing negative or negligible profit and profitability.

These trends lead to a steady decrease in the margin between the market prices of honey and the cost, and thus to profit and profitability. For the analysed period average prices on the conventional markets of conventional honey decreased by EUR 0.409 kg⁻¹, and in the consumer markets by EUR 0.512 kg⁻¹, while in the organizational organic markets they decreased by EUR 1.125 kg⁻¹ and in the consumer markets by EUR 0.716 kg⁻¹. At the same time, the cost is growing steadily, with organic honey growing much higher than conventional production, respectively reducing margins and profits are even greater.

Table 5

Expenses of conventional honey in the region of Ruse

Expenses	EUR hive ⁻¹	EUR kg ⁻¹	%
1. Salary (amount of 1.1 – 1.4 = 4 hours)	14.97	0.75	37.09
1.1. Labor – harvesting (removal / return of frames, extracting, filtering - 2 hours)	7.49	0.37	
1.2. Labor – examinations (basic, swarming, informational, etc. – 1 hour)	3.74	0.19	
1.3. Labor – nourishment (0.5 hours)	1.87	0.09	
1.4. Labor – prevention (varroaosis and other diseases – 0.5 hours)	1.87	0.09	
2. Self – insurance (31.3% of salary)	4.69	0.23	11.61
3. Depreciation (10% of the hive price)	5.11	0.26	12.67
4. Repair (3% of the hive price)	1.53	0.08	3.80
5. Feeding – autumn EUR 5,11, spring EUR 3.07	8.18	0.41	20.27
6. Medical supplies – autumn / spring EUR 2.05, etc.	3.07	0.15	7.60
7. Unpackaging (tins – 25 kg, etc.)	1.79	0.09	4.43
8. Transport	1.02	0.05	2.53
All production cost	40.36	2.02	100.00
1. Packaging (decrySTALLIZATION, filtration, homogenization, packaging and labelling)		0.46	
2. Packaging (glass jars, labels)		0.18	
3. Transport		0.03	
4. Marketing (research, advertising, etc.)		0.03	
All complete cost price		2.71	
Share of production cost in total			74.53

Legend:

Bee hive – Dadant blatt system

Yielding conventional honey bouquet 20 kg per year.

Hourly payment (1 time min. EUR 311.89) – EUR 3.74 h⁻¹

At the end of the analysed period, the gross profit per unit of production of bee honey in distribution on the national conventional organizational markets was EUR 0.275 kg⁻¹. Farmers in Bulgaria pay a 10% tax on 40% of their turnover at 60% of the normative recognized costs. The net profit in the same markets is EUR 0.185 kg⁻¹. The apiaries in the Ruse region do not realize gross and net profit on organic honey on the national organizational organic markets – Table 7. The gross margin for distribution on the consumer conventional markets is EUR 1.15 kg⁻¹. The net profit in the same markets after paying 20% value added tax on the final price is EUR 0.39 kg⁻¹. The gross margin on sales on the national consumer organic markets is EUR 1.485 kg⁻¹ and the net profit is EUR 0.455 kg⁻¹ – Table. 8.

The data in Table 7 and Table 8 shows that the apiaries in the Ruse district achieve the highest net profitability of the turnover on the consumer conventional markets – 10.26%. In the consumer organic segment, their profitability was 8.83%, in the conventional organizational segment it was 8.2%, and the organizational organic segment it was unprofitable.

The negative trends in honey prices, which continued to decline in early 2020 and the steady rise in self-value cost, has led to a sustainable decline in the profitability of apiaries.

From the data obtained and shown in Table 7 and Table 8, we can also determine the annual net profit of apiaries in the Ruse region. With an average yield of 20 kg per hive conventional honey and placement on organizational markets, the net profit per hive is EUR 3.78 year⁻¹ and in the consumer markets – EUR 7.98 year⁻¹. With an average yield of 17 kg per hive of organic honey and placement on the consumer markets, the net profit is EUR 7.91 year⁻¹. Therefore, apiaries from Ruse with 1000 hives, which sell honey on the organic consumer markets, will realize a net profit of EUR 790.969 year⁻¹, and when sold on the conventional consumer markets – EUR 797.615 year⁻¹.

Determining the cut-off point (revenue = cost), it also allows the calculation of the hive gross profit. When production costs are relatively constant, the critical point is:

Table 6

Expenses of organic honey in the region of Ruse

Expenses	EUR hive ⁻¹	EUR kg ⁻¹	%
1. Salary (amount of 1.1. – 1.4 = 4.2 hours)	14.47	0.85	27.84
1.1. Labor - harvesting (removal / return of frames, extracting, filtering – 2 hours)	6.89	0.41	
1.2. Labor – examinations (basic, swarming, informational, etc. – 1 hour)	3.45	0.20	
1.3. Labor – nourishment (0.5 hours)	1.72	0.10	
1.4. Labor – prevention (varroaosis and other diseases – 0.7 hours)	1.72	0.10	
2. Self – insurance (31.3% of salary)	4.53	0.27	8.72
3. Depreciation (20% of the hive price)	10.23	0.60	19.67
4. Repair (4% of the hive price)	2.05	0.12	3.93
5. Feeding – autumn EUR 7.67, spring EUR 5.11	12.78	0.75	24.59
6. Natural medical supplies – autumn /spring EUR 3.07 and others	5.11	0.30	9.84
7. Packaging (tins – 25 kg, etc.)	1.79	0.11	3.44
8. Transport	1.02	0.06	1.97
All production cost	51.98	3.06	100.00
1.Unpackaging (decrystallization, filtration, homogenization, packaging and labelling)		0.46	
2. Packaging (glass jars, labels)		0.18	
3. Transport		0.03	
4. Marketing (research, advertising, etc.)		0.03	
All complete cost price		3.75	
Share of production cost in total			81.58

Legend:

Bee hive – Dadant blatt system

Yielding an organic honey bouquet 17 kg per year.

Hourly payment (2 time min EUR 311.89) – EUR 3.74 h⁻¹

Table 7

Profitability of honey in organizational market

	Conventional	Organic
Market Price (), EUR kg ⁻¹	2.30	2.86
Commercial cost (), EUR kg ⁻¹	2.02	3.06
Gross profit (), EUR kg ⁻¹	0.28	- 0.19
Tax (1), EUR kg ⁻¹	0.09	-
Net profit (), EUR kg ⁻¹	0.19	-
Wn per beehive (), EUR year ⁻¹ .	3.78	-
Wn per 1000 beehive (), EUR year ⁻¹ .	3.783.56	-
Profitability of turnover).100, %	4.19	-

$$Qb = \frac{Sm}{Pe} \quad (1)$$

$$Wm = Pe - Sm \quad (2)$$

Legend:

Qb – critical point; *Sm* – production cost; *Pe*– market price; *Wm*– gross profit

At an average yield of 20 kg per hive of honey, the critical point is $Qb = Sm.20 / Pe$. In the market for organizational conventional markets $Qb = 3.95.20 / 4.5 = 17.55$ kg. Apiaries in the Ruse region will start to make a gross profit of more than 17.55 kg hive⁻¹. At an average yield of 20 kg, gross profit $Wm = (20 - 17.55) .4.5 = EUR 5.625$ hive⁻¹. Therefore, apiaries

Table 8

Profitability of honey in consumer markets

	Conventional	Organic
Market Price (), EUR kg ⁻¹	3.89	5.27
Commercial cost (), EUR kg ⁻¹	2.71	3.75
Gross profit (), EUR kg ⁻¹	1.18	1.52
Tax (), EUR kg ⁻¹	0.78	1.05
Net profit (), EUR kg ⁻¹	0.40	0.47
Wn per beehive (), EUR year ⁻¹ .	7.98	7.91
Wn per 1000 beehive (), EUR year ⁻¹ .	7.976.15	7.909.69
Profitability of turnover ().100, %	5.25	4.51

from Ruse with 1000 hives, which sell honey on the conventional organizational markets, will make a gross profit of EUR 562.421 year⁻¹.

The apiaries cannot independently influence honey prices, and in order to improve their income and profitability, they must reduce their costs. This can be done in two main ways – extensive and intensive. The first is based on quantitative factors through which the advantages of the wholesale over small production are realized, and the second on the qualitative factors – an increase in the average hive yield, selection of bee colonies, improvement of the quality of honey produced, a more complete production capacity utilization, etc.

Large beekeeping production creates better conditions for the application of science and technology, for the introduction of high-performance machinery, technologies and complex forms of cooperation and division of labour, advanced technology and organization of production and marketing. Apiaries in the Ruse district can achieve this by integrating and intensifying production – achieving higher rates of productivity growth than those of the average wage, introducing better technologies and more.

The apiaries must pursue a targeted sectoral policy to introduce beehive subsidies due to two serious arguments: 1) providing an ecosystem-based pollination service, which has a fundamental role and importance for the conservation of biodiversity and the sustainable development of agriculture; 2) improving the profitability of apiaries, taking into account negative and much lower values compared to other sectors – industrial, services, etc. They are also in line with the implementation of a social agricultural policy for providing healthy food at affordable prices.

The apiaries should not rely solely on state and Community policies. They need to develop marketing strategies that allow them to achieve competitiveness and profitability in the markets for bee products (pollen, royal jelly, etc.) and their specific segments –

target markets. It is necessary to design high value-added bee products that allow higher and more sustainable prices. The apiaries should be integrated into a regional, horizontal and vertical plan – with industries to reduce the cost of bee products.

We can summarize that the main role in reducing the cost of apiaries is the introduction of better technologies and organization, the achievement of higher labour productivity, the increase in the average hive production and the regional integration of apiaries that facilitates them. The main factors for increasing the revenues are the achievement of higher prices, provision of subsidies – pollination, etc., diversification of activities – promoting tourism, trade, etc. Marketing plays a key role in increasing the income of apiaries.

Conclusions

1. The surveyed market prices and the prime cost of honey from apiaries in the region of Ruse show that they achieve a small net profit when selling conventional honey on the organizational markets – EUR 3.78 kg⁻¹. The placement of organic honey as a raw material on the organizational markets is not profitable for them. In the distribution of consumer markets, they reach a net profit of EUR 7.98 kg⁻¹ for conventional and EUR 7.91 kg⁻¹ for organic honey. In an organic farm with 1000 hives, it is EUR 790.969 i.e. very low.
2. The apiaries in the Ruse region have 10.26% commercial profitability of the costs in marketing to conventional consumer markets, 8.83% in organic consumer markets and 8.2% in organizational conventional markets. Organic honey sales, as a raw material on organizational markets are unprofitable. Given the high volatility of honey prices, there are periods in which cost-effectiveness will be much lower.
3. The downward trend in bee market prices and the increase in its cost price lead to a decrease in profitability of the business. Measures must

be taken to stabilize prices and reduce costs. Horizontal and vertical integration of apiaries is needed in order to achieve competitiveness and profitability. Markets and marketing set the directions for integration.

4. Sectoral and cross-sectoral integration will improve revenues by forming bee products with high added value and high sustainable prices, diversification of incomes, preservation of biodiversity, subsidies – pollination and more. It will reduce prime cost by realizing the wholesale advantages prior to small-scale production that allow for better specialization, better technology, higher productivity and higher hive yields.
5. Increasing the profitability of apiaries requires:
 - 1) marketing strategies to achieve profitability and

competitiveness at the trans-regional level through regional and cross-sectoral integration, 2) the production of bee products with high added value, incl. outside the category of traditional and most widely produced honey and wax, 3) introduction of new technologies, increase in labour productivity and average hive production, and 4) state subsidies assigned to a hive for ecosystem pollination service.

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INNOVATION AS A FACTOR OF THE LABOR RESOURCES OF RURAL AREAS RESERVE

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Abstract

The article considers the prospects of innovative entrepreneurship in the preservation of labor resources and attracting young people to ensure sustainable development of rural areas.

Rural areas of Ukraine due to social, economic, cultural, demographic and environmental processes lose their attractiveness for the population, which is mainly employed in their own households, such work in most cases leads to the loss of skills, is inefficient, exhausting and does not provide the desired standard of living. According to the results of modelling, which is presented in the article, the biggest part of population over the next decade is likely to focus on areas of activity related to intellectual work that requires higher education. As the opportunity to realize such advantages in rural areas is extremely limited, while maintaining modern conditions, the tendency to reduce the human potential of rural areas will increase. Therefore, according to the experience of the most competitive regions of the world, it is important for Ukraine to form and develop entrepreneurial regional innovation systems, whose main features are mobility, the ability to quickly respond and adequately change external operating conditions. In such systems, new knowledge is transferred between research centers and business structures through both formal and informal channels, by involving scientists in the implementation of innovative projects. Nowadays, about 20% of students want to get a modern higher education and after graduation to work in rural communities as entrepreneurs, but the ambition is higher and the current stage of the development shall be a transformational transition of rural regions of Ukraine to the model of innovative economy.

Key words: rural areas, labor resources, innovation, entrepreneurship.

Introduction

Negative trends in social, economic, cultural, demographic and environmental processes exacerbate the differences between living standards and economic development of the rural and urban areas. A common feature of the rural areas was the deterioration of the environment due to excessive land use in agricultural production, intensification of subsoil development by quarrying and exacerbation of the problem of garbage management. Relatively stable rules, methods and technologies that have succeeded in the past are no longer adequate to the current conditions of the rural economic development. This requires finding solutions aimed at achieving long-term goals in conditions of uncertainty, unpredictability and instability of the market environment. Achieving the goals of sustainable development of rural settlements in Ukraine requires the involvement of young people – the most productive, innovative and flexible members of society among the rural population. In the research, we tried to analyse the modern status of the innovation development of the rural areas of Ukraine, youth plans for the future and their connection to the rural areas and build a model for the forecast, which becomes one of the basis for the creation of the results of research.

Materials and Methods

According to Joseph Schumpeter, 'Innovation is the only function that is fundamental in history' (Schumpeter, 1939). Schumpeter argues that innovation is the basis of economic growth, insisting that entrepreneurship itself contributes to the

development of economic history. He also stressed that entrepreneurship itself 'replaces today's Pareto optimum with tomorrow's new thing,' transforming business practices so that they benefit the environment and society.

In the Strategy of the sphere of innovation activity development for the period up to 2030 approved by the Cabinet of Ministers of Ukraine on July 10, 2019 (Verkhovna Rada of Ukraine, 2020a) it is stated that in Ukraine there is a gradual degradation of innovation potential. To remedy the situation, it is declared to promote the development of high-intensity activities, i.e. the transition from low-tech resource to high-tech innovation economy, the focus of the public policy on creating favorable conditions, especially for the development of intellectual products, including their commercialization in Ukraine and the rest of the world.

Accordingly, the strategic directions of the Ukrainian regions' development shall be the strengthening of the knowledge-intensive economic activities that form V-VII technological systems: the fifth – electronic, measuring, fiber-optic technology, software, telecommunications, robotics, information services; sixth – nanoenergy, molecular, cellular, nanotechnology, nanobiotechnology, nanobionics, microelectronic technologies, nanomaterials, etc.; seventh - instrumentation and robotics, biocomputer systems and biomedicine, communication of artificial and organic systems. Today, new business ideas are primarily generated in agglomerations and large cities, where new concepts of sustainable development are

being implemented. Thus, the headquarters of the most companies in the information technology industry are located in the main IT centers of the country – mm. Kyiv, Kharkiv, Lviv, Dnipro and Odesa (Verkhovna Rada of Ukraine, 2020b).

The relationship between innovative entrepreneurship and conservation of labor resources in rural areas, attracts increased attention in the context of finding solutions that can ensure the achievement of sustainable development goals. The research methodology is based on methods of analysis and synthesis, modeling, interpretation and relevant comparisons.

Results and Discussion

Consider the Global Innovation Index, jointly published by Cornell University, the European Institute of Business Administration and a specialized agency of the World Intellectual Property Organization in order to identify trends in the innovative development of Ukraine’s economy. Recognizing that innovation is a key driver of economic development, GII conducts and publishes rankings and analyzes of the situation in 131 economies around the world. The index measures innovation based on criteria that include: institutions, human capital and research, infrastructure, loans, investments, connections, creation, absorption and dissemination of knowledge, results. The 2020 report identifies Switzerland as the most innovative country, followed by Sweden, the United States and the United Kingdom. Ukraine ranks 45th in the Global Innovation Index 2020, entering the TOP-2 countries of the economic group with lower-middle income (Global Innovation Index 2020, 2020).

Ukraine, unfortunately, lags behind neighbouring countries in terms of innovation, ranking 30th among 39 European countries (Global Innovation Index 2020 Ukraine, 2020).

The main indicators of the innovation potential of the regions correspond to the trends shown by Ukraine’s rating according to the global innovation index. Due to the fact that individuals form the innovative potential of the region, we see a tendency to reduce the number of students in graduate school and doctoral studies, training of highly qualified researchers, for example, only in the Mykolaiv region

during the last three years decreased by 61 people (Main department of statistics in the Mykolaiv area, 2020), Table.1

The high need of the economy for highly competitive scientific and technical developments is not provided with financial resources, in 2016–2019 there was a significant reduction in the cost connected with research and development in the region from all sources, Figure 1.

The lack of funding has a negative impact on the creation of intellectual property. According to the State Enterprise “Ukrainian Institute of Intellectual Property” (Ukrpatent), which is an institute of the state system of legal protection of intellectual property in Ukraine, national applicants filed 2,097 applications for inventions in 2019 (over 54% of the total). Most applications came from applicants from Kyiv city (34.5%), Kharkiv (16.5%), Dnipro (9.2%), Odesa (6.9%), Lviv (4.5%), Donetsk (3.5%), Kiev (3.0%) and Vinnytsia (2.4%) areas, from the Mykolaiv region – only 24 applications (1.1%), the smallest number of applications, on 4 (0.2%) – were received from Volyn and Chernivtsi regions (Ukrpatent, 2019).

In 2019 in the Mykolaiv region from the total number of subjects of management – 56 309 units, only 7 belonged to a category of big enterprises, and 78% are subjects of small business which are capable to react quite dynamically and flexibly to changes both in consumer demand, and on new perspectives that open up in the implementation of research results. Under the crisis conditions associated with the threat of COVID-19, a significant advantage of small innovative enterprises is their ability to innovate, which at the first stage does not require significant investment and attract a significant amount of labor and material resources. It is especially important to create new jobs for professionals who are able to work in search of new solutions, and, above all, it may be young scientists.

Thousands of young professionals in the field of agriculture, the vast majority of whom will look for work in the city, annually graduate from higher education institutions. After conducting a survey among students of Mykolayiv National Agrarian University, we found that about 77% of respondents express a desire to live in the city and work in the areas

Table 1

Training of scientific personnel of the highest qualification in the Mykolaiv area

Indicators	Years					
	2016		2017		2018	
	units	persons	units	persons	units	persons
Postgraduate studies	5	205	5	174	5	156
Doctoral studies	4	25	4	21	4	13

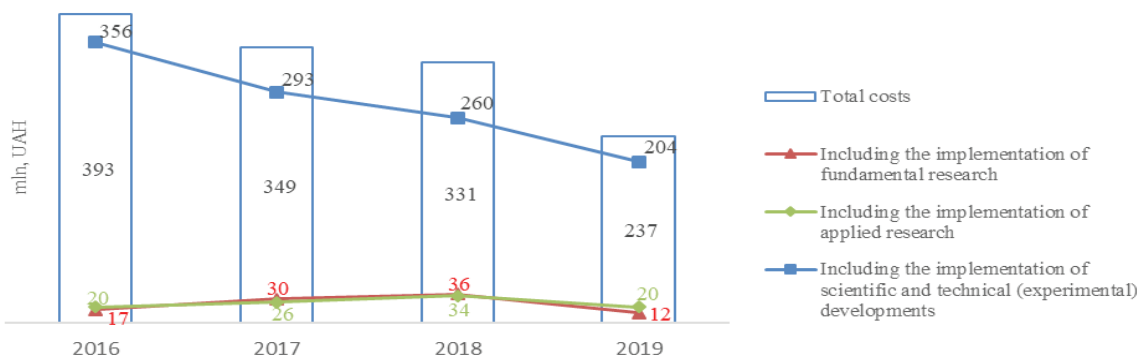


Figure 1. The cost of research and development by types of work in the Mykolaiv region, (thousand UAH) (Main department of statistics in the Mykolaiyv area, 2020).

not related to agriculture. Such answers quite clearly reflect the attitude of young people to the village, because the difference in living standards between the village and the city is huge, and among the main priorities that determine their choice, students identify economic points. In addition, part of the students talk about the lack of an adequate social environment. Such answers also suggest that without global change in the nearest future we shall not expect a large flow of graduates who will go to work in rural communities, which will worsen the already catastrophic situation in the Ukrainian countryside.

Today, there is a clear group of students (about 20%) who want to obtain a modern higher education and after graduation work in rural communities as entrepreneurs. Therefore, the priority of regional policy should be the preservation of labor resources of rural areas, their human resources, and in light of current trends it is urgent not only to retain specialists but also to attract a significant number of new ones.

Using stochastic modeling to predict the behavior of socio-economic systems, calculations were performed to determine the most probable directions of development of the current conditions, in terms of the advantages in choosing the field of professional activity. The set of all possible professions Ω was conditionally divided into subsets of A_i , which are called occupational classes. Despite the fact that any probabilistic model describes the real process less accurately than the deterministic one, and is not able to predict changes in its parameters, this model allows to predict the expected average values of the required parameters quite satisfactorily from a practical point of view. It is also taken into account that a wide range of real processes are probabilistic in their internal structure, so that they cannot be adequately described using deterministic models. We used Markov chains, which are used as a mathematical apparatus of research in many fields, such as economics, ecology and sociology.

We have a system S , which at any given time can be in one of N incompatible probable states:

$$\omega_1, \omega_2, \dots, \omega_i, \dots, \omega_N \tag{1}$$

and can change these states at different points in time, then for the Markov chain the conditional probability of the system to go to any possible state ω_i depends only on the state in which the system was at the previous time and does not depend on the states in which the system was in earlier moments of time. The general probabilistic picture of all possible transitions of system from one state to any other is set by a matrix

$$\pi = \begin{matrix} & \omega_1 & \omega_2 & \dots & \omega_j & \dots & \omega_N \\ \omega_1 & P_{11} & P_{12} & \dots & P_{1j} & \dots & P_{1N} \\ \omega_2 & P_{21} & P_{22} & \dots & P_{2j} & \dots & P_{2N} \\ \dots & \dots & \dots & \dots & \dots & \dots & \dots \\ \omega_i & P_{i1} & P_{i2} & \dots & P_{ij} & \dots & P_{iN} \\ \dots & \dots & \dots & \dots & \dots & \dots & \dots \\ \omega_N & P_{N1} & P_{N2} & \dots & P_{Nj} & \dots & P_{NN} \end{matrix}, \tag{2}$$

if the condition is met

$$\sum_{j=1}^N P_{ij} = 1 \quad i = \overline{1, N}. \tag{3}$$

Where P_{ij} – the probability of transition of the system from the state ω_i to the state ω_j .

Matrix (2) is a one-step transition matrix. If there is a number k at which from any state of the chain it is possible to move to any other in k steps, then such a chain is regular.

For any probability vector \vec{a} vector $\vec{a}' \pi^k$ will go to the vector \vec{W} with $k \rightarrow \infty$, that is

$$\lim_{k \rightarrow \infty} \vec{a}' \pi^k = \vec{W} \tag{4}$$

\vec{W} - a vector that has the following property

$$\vec{W}' \pi = \vec{W}' \tag{5}$$

Condition (4) should be interpreted as follows - regardless of the initial state of the vector \vec{a} of the system for regular Markov chains

$$\vec{a} \pi^k \xrightarrow{k \rightarrow \infty} \vec{W} \tag{6}$$

Vector \vec{W} is a vector of stationary (final) probabilities, the components of which satisfy the condition

$$\sum_{i=1}^N W_i = 1 \tag{7}$$

During the research the model of mobility of professions under change of generations on the basis of regular Markov chains for the Mykolaiv region was constructed, solved and analyzed. The input data for the model were statistical data on the structure and population in terms of areas of activity in the Mykolaiv region and Mykolaiv city for 10 years.

The choice of specific individuals for further professional activity in the intellectual or physical sphere, or in the field of agricultural production, in rural areas, is described by a matrix of regular Markov chains. The elements of the matrix inform about the average share of young people in the future to choose a profession.

Based on the results of statistical data processing, a matrix of one-step transition is constructed, which

describes the general probabilistic picture of all possible transitions of the system from one state to any other, which has the form (2).

The vector of stationary (final) probabilities of states of the system W is defined as

$$W = \lim_{n \rightarrow \infty} \pi^k \tag{8}$$

n – the number of system states, k – number of forecast steps.

We have eight (N=8) system states:

– areas of activity which are typical for rural areas – ω_1 – low-skilled manual labor that does not require special education, ω_2 – work that requires special secondary education (mechanics, etc.), ω_3 – skilled work that requires higher education (technologists, veterinarians, agronomists, accountants, economists, administration, etc.), ω_4 – scientific activity in agriculture;

– areas of activity which are typical for the city – ω_5 – low-skilled manual labor that does not require special education, ω_6 – work that requires special education, ω_7 – intellectual work that requires higher education, ω_8 – research activities.

The largest share of the population is likely to be focused on areas of activity related to intellectual work that requires higher education. As the opportunity to realize such advantages in rural areas is extremely limited, while maintaining modern conditions, the tendency to reduce the human potential of rural areas will increase. Therefore, it is necessary to create and develop innovative activities in rural areas, in our opinion, this will contribute to the strengthening of post-industrial society in Ukraine, because it is characterized by active use of “Internet”, allows you

Table 2

Initial matrix

	ω_1	ω_2	ω_3	ω_4	ω_5	ω_6	ω_7	ω_8
ω_1	0.294	0.209	0.121	0.001	0.135	0.126	0.113	0.001
ω_2	0.023	0.311	0.219	0.005	0.089	0.121	0.198	0.034
ω_3	0.013	0.104	0.381	0.009	0.140	0.029	0.256	0.068
ω_4	0.001	0.012	0.108	0.424	0.001	0.048	0.231	0.175
ω_5	0.087	0.069	0.073	0.001	0.452	0.112	0.178	0.028
ω_6	0.000	0.001	0.098	0.002	0.085	0.331	0.388	0.095
ω_7	0.000	0.000	0.029	0.006	0.096	0.141	0.525	0.203
ω_8	0.000	0.000	0.009	0.039	0.015	0.211	0.453	0.273

Vector stationary probabilities

$$\vec{W} (0.019 \quad 0.032 \quad 0.081 \quad 0.017 \quad 0.131 \quad 0.168 \quad 0.401 \quad 0.152)$$

to work physically away from work. A sufficiently high level of knowledge of such people, as well as members of their families can be an additional factor in the development of the territory. Examples of such an approach we are already seeing in rural areas, which are located near regional centers or large cities. Low levels of infrastructure are also problematic issues in the practice of rural decision-making: poor roads, insufficient transport services, low levels of education and health care, that is why these areas should be considered prior to others for public policy. Initial matrix, Table 2.

According to the American sociologist and economist R. Florida, ‘Natural resources and even large corporations are no longer drivers of economic progress, but the ability of cities to unite and concentrate talented people, create opportunities for them to combine and redistribute ideas and efforts, significantly enhances our innovation and productivity’ (Cooke, 2003).

Therefore, according to the experience of the most competitive regions of the world, it is important for Ukraine to form and develop entrepreneurial regional innovation systems, which feature mobility and the ability to respond quickly and adequately to changing external operating conditions. In such systems, new knowledge is transferred between research centers and business structures through both formal and informal channels by involving scientists in the implementation of innovative projects funded by venture capital (Florida, 2017).

According to the modern tendencies in the Mykolaiv region, implementation of the project Innovation cluster “Regional innovative HUB” began. The Mykolaiv region became the winner of the competitive selection of grant projects at the expense of EU. RInnoHUB focuses its efforts on the implementation of the following chain “science, knowledge, experience – idea – project – experimental design – investor attraction – production – sales – income – taxes”. As a result of such implementation, the number of innovative enterprises is expected to grow by 15% every year. Innovation cluster

“RInnoHUB” offers: knowledge in various areas of business; business coaches and mentors with extensive experience in implementing projects of varying complexity; business consultations, startup ecosystems; convenient coworking; a laboratory where it is possible to create any prototype of a future bestseller; comprehensive support of the startup at Ukrainian and international competitions; ideas generation courses.

The work of the experimental group “Creative Laboratory” has begun. So, the innovation potential of the region is being developed, and the culture of training networks for entrepreneurs and institutions that generate and use knowledge is spreading, which strengthens the prospects for generating new innovative projects.

Conclusions

Strengthening the innovation potential of the rural areas, through the optimal use of available resources and competencies are of particular importance in conditions of fierce competition. Dynamization of innovation activity is today one of the priorities of regional development.

According to the research the largest share of the population is likely to be focused on areas of activity related to intellectual work that requires higher education and currently only a small part of the young specialists want to connect their life with the rural areas and develop there own businesses there. However, even this part of the youth has not enough possibilities and enough support to realise their ideas within the rural areas of Ukraine.

The current stage of development for the regions of Ukraine should lie in the field of a transformational transition to the model of innovative economy. This goal requires strengthening and effective implementation of the innovation potential, based on the formation of effective regional innovation systems, namely: the presence of a developed mechanism of technology transfer, effective innovation infrastructure, institutional structure, and the establishment of informal partnerships.

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DEMAND FOR SOCIAL FARMING SERVICES IN LATVIA: DEMENTIA CARE IN RŪJIENA MUNICIPALITY

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Abstract

The aim of the study is to explore potential demand for social care services offered by social farming in Latvia by studying the experience of families caring for family members with dementia. Social farming is both a new and a traditional concept. It originates from the traditional rural self-help networks that were well established in rural areas before the modernisation of agriculture and the rise of the public welfare system. Social agriculture covers at least three dynamic areas of society – rural development, social entrepreneurship and the growing demand for social care services, and it is closely linked to the concept of multifunctional agriculture. As a form of social entrepreneurship, social farming could create the opportunity to reconnect farmers with their local communities through the opening of their farms as part of the social support system of the community. Caring for people with dementia is a particular challenge. Currently in Latvia, families where one of the family members has dementia have only two options - to place their relatives in a care institution or to take care of them in the family. Foreign experience shows that social care farms can provide care services to people with early dementia. This paper, exploring demand for these services in Latvia, is based on the case study of families caring for persons with dementia in Rūjiena municipality in April 2020.

Key words: social farming, rural development, multifunctional agriculture, social entrepreneurship, dementia care.

Introduction

Social farming is an emerging topic for different stakeholders – farmers, farmers’ organisations, service-users of social farms and their organisations, providers of social and health care services, other stakeholders in social and health care and local, regional and national authorities. Social farming is both a new and a traditional concept. It originated from the traditional rural self-help networks that were well established in rural areas before the modernisation of agriculture and the rise of the public welfare system. Social farming fits with the changing needs in society. It is interesting for the social and health care sectors, as it is linked to the strong demand for inclusive development coming from the fields of social and health care services. In general, social farming covers at least three dynamic areas of society – rural development, social entrepreneurship and the growing demand for social care services; it is closely linked to the concept of multifunctional agriculture.

Today’s endogenous and neo-endogenous approach to rural development in Europe implies development in its broadest sense, meaning not only traditional agricultural sectors but also diversified local economies, social inclusion and the involvement of more active communities in development processes (Galdeano-Gómez, Aznar-Sánchez, & Pérez-Mesa, 2011). Multifunctional agriculture function refers to the provision of goods and services that ‘satisfy societal needs or demands’ and the end consumer is also human (Wiggering *et al.*, 2006).

Agricultural multifunctionality is closely associated with farm diversification which itself can take many various forms (Knickel & Renting, 2000).

In rural development context social farming could be analysed as one form of diversification of farming that is becoming increasingly common in many European countries (de Krom & Dessein, 2013). Multifunctionality, a core issue in the EU agricultural and rural development agenda, refers to the different functions that agriculture fulfils in society, functions that go well beyond the production of food and fibres (Bassi, Nassivera, & Piani, 2016).

Rural social environment is related to peculiarities of economic structure, demographic processes. Latvia is characterized by a large number of small farms (85%) with significant economic and social disparities, which also have a territorial impact. Small farm output and, consequently, incomes are relatively small, contributing to social stratification. The age structure of farm holders shows that in the group of small farms are twice time more owners above the age 65 years as it is in groups of medium and big farms’ owners. Small farms use 43% of agricultural land with a relatively low level of production (27% of standard output). Small farms have a relatively large number of employees – 76% of those employed in agriculture. The number of farms in Latvia is shrinking. According to the data of the Farm Register, between 2005 and 2016, the number of farms decreased from 133 thousand up to 82.4 thousand or by 38%, which are mainly small farms (AREI, 2017); therefore, the acquisition of new economic activities and the diversification of income sources are important for the survival of small farms.

Small farms are an important support for the employment of the rural population, maintenance of the natural environment and traditional cultural landscapes, ensuring biodiversity. These farms create

an aesthetic rural environment, offer new recreational and health services, produce regional cuisine, establish short food chains, operate in an environmentally friendly manner, and use organic farming methods. These farms mark new trends in rural development, such as part-time farming, lifestyle farms, pension management, educational, social care, rehabilitation, therapeutic functions, agricultural diversification, artisan food processing. (Wilson, 2007; Zasada, 2011; Braastad & Hauge, 2007; De Krom & Dessein, 2013). Social farming would create new employment and income opportunities, allow small farms to survive in the future. Many European countries have considerable experience in social farming - social care farms in Ireland, the Netherlands, Finland, Norway and elsewhere are successfully developing social care services. In these countries care farms develop an idea of multifunctional agriculture by organizing social services on the local level. Poland – a new member of the European Union, supported by the same legislative framework and programme objectives of the EU in the area of green care could be mentioned among these countries. Like other new members of the EU, Poland represents the country with no strong social welfare system like in Nordic countries. Poland in the programming period 2014–2020 was the biggest beneficiary of Cohesion Policy funds and therefore could afford bigger investments in social farming. This solution is quickly developing in the country (Wojcieszak, 2018).

Healthcare systems across the world are experiencing increased financial, organizational and social pressures attributable to a range of critical issues including the challenge of ageing populations. Health systems need to adapt to sustainably provided quality care to the widest range of patients, particularly to those with chronic and complex diseases, and especially to those in vulnerable and low-income groups. Referring to global demographics and technological developments, health care experts note: ‘the gap between urban and rural areas continues to grow due to the disproportionate concentrations of resources and health services in cities. Ageing populations will lead to a shift of focus towards long-term and chronic care, in comparison to treatments in acute settings. To counterbalance these issues, healthcare services should ideally be decentralised and flexible, and better at coordinating efforts for patients to move from provider-centric care to primary-, community- and patient-centric care’ (Amalberti, Nicklin, & Braithwaite, 2016).

The consequences of aging population affect the entire EU due to increasing life expectancy and consistently low levels of fertility over recent decades. The trend is expected to continue in the coming decades (European Commission, 2015). The challenges that

come with a rapidly aging population establish new relations between family, community and caregiver organizations (Hollinrake & Thomas, 2015).

At the same time, entrepreneurs see new opportunities in this service sector. This is evidenced by statements such as ‘seniors are the health care industry’s gold rush’. Policymakers throughout Europe have worked on tackling the societal challenge of an ageing population in Europe for many years. Initially, there was a focus on maintaining public spending on health and care and pensions sustainable in the short and long term. This focus has since been extended and increasingly the challenge of an ageing population is being tackled more comprehensively as an opportunity, involving technologies and social innovations, and identifying cross-cutting solutions to improve the general health and wellbeing of the older adults. There has also been a greater recognition that while the Silver Economy represents private and public consumption that serves the needs of older people, many indirect and induced effects provide opportunities for both the older and younger generations (European Commission, 2018)

In rural development too, the aging of the population is both a challenge and an opportunity. Social farming is one the most significant examples of social innovation in rural areas. Social farming is a response to changes in agriculture and rural lifestyle in communities across rural Europe. Social farming as a form of social entrepreneurship could create the opportunity to reconnect farmers with their local communities through the opening up of their farms as part of the social support system of the community.

Caring for people with dementia is a particular challenge. Dementia is a progressive disease that affects multiple levels of functioning. People with severe cognitive impairment need help in almost all aspects of daily life, but it is important to provide appropriate care at an early stage in order to distance the patient from losing his or her functional independence and improve his or her life during illness. Foreign experience shows that social care farms can provide care services to people with early dementia, extending the time when the need arises to place them in long-term care facilities (de Boer *et al.*, 2019). It has been reported that cognitive decline could be prevented, and the onset of Alzheimer’s disease could be delayed if people with mild cognitive impairment are mentally active and frequently participate in social activities (Hsiao, Chang, & Gean, 2018). This care model could also be suitable for Latvian conditions, especially in remote areas, where the costs of social services provided by the public sector are high and where there are many small and medium-sized farms, where social entrepreneurship would allow diversification of income.

The experience of other countries shows that the social care services offered by social farming can ensure the sustainability of small and medium-sized farms, improve the availability of social services in remote areas. Although ensuring the quality and wide availability of these services is a key challenge in countries where the purchasing capacity of a large part of the population is low, the benefits are significant. Currently in Latvia, families where one of the family members has dementia have only two options - to place their relatives in a care institution or to take care of them in the family. Placing people with dementia in social care institutions with many clients in families is often seen as a last resort. Although family caregivers face serious difficulties, families only choose this option if family care is no longer possible.

Working with people with dementia requires holistic support and help – to maintain his social network, to strengthen his individuality, to give him the ability to self-determination, to inform him, to promote his independence and to promote factors that improve his quality of life. For people with mild cognitive impairment who are mentally active in a family environment, maintaining a normal lifestyle and moderate physical activity in social care farms may defer the need for care in institutions until later, even if there are no conditions in the family to care for them. Even if the family is willing and able to care for their family member with dementia, situations may arise where the use of services of social care farms may be necessary on a temporary basis. The aim of the study is to explore potential demand for social care services offered by social farming in Latvia by studying the experience of families caring for family members with dementia.

Materials and Methods

The core research methodology for obtaining and analysing empirical data in this qualitative study was the case study approach. This paper is based on case study of families caring for patients with dementia in Rūjiena municipality in April 2020. Case study is a research approach and a strategy that uses different methods of collecting data: quantitative, qualitative, desk study, etc. Case studies are generally characterised by the potential localisation of a specific research topic in terms of their diversity (Yin, 2014).

In this study the main research tool was in-depth explorative interviews with family caregivers taking care of persons with symptoms of dementia and diagnosed dementia. Family doctors, representatives of care institutions and other specialists involved in the care of people with dementia were also interviewed. In the interviews, the family members talked about their experience in caring for relatives with dementia and what support they would need.

Three families from Rūjiena municipality living in different circumstances were included in the study using convenience sampling.

Written or verbal consent for participation in the study was obtained from participants prior to the interview. Due to the restrictions imposed by the Covid-19 pandemic, the interviews were conducted by telephone.

Results and Discussion

Rūjiena municipality is in the northern part of Latvia, about 150 km from the capital Riga. In 2018 more than half – 56% – of the 5154 inhabitants of the municipality lived in town. Municipality has a relatively good infrastructure of health care and social services - two social care centres and a social care and rehabilitation institution.

A stable health care system has been established in Rūjiena region, where outpatient health services (family doctor, gynaecologist, physiotherapist, surgeon, X-ray diagnostic room) are provided. The social care system in Rūjiena consists of the municipality's Social Service agency, psychologist, private long-term care and rehabilitation centre, municipal and state care institutions. State social care centre Vidzeme branch 'Rūja' is a long-term social care institution for persons with mental disorders, and it has 270 clients. Association 'Rūjienas senioru māja' is a private long-term care and rehabilitation institution for various types of clients (a total of 100); it also offers a day-care service. Social care centre 'Lode' is a municipal long-term social care institution, which has 83 clients. In general, the population in municipality has quite good access to health and social care services.

Family composition, living conditions and level of material well-being affect the ability to care for a relative with dementia, so families living in different circumstances were included in the study.

Family No1 lives in a three-room apartment on the third floor of an apartment building. A person with dementia, a 79-year-old woman, lives with her daughter, son-in-law and granddaughter. The daughter and her husband are of working age and are at work during the day, the granddaughter is a schoolgirl. Dementia (Lewy body dementia) was diagnosed in April 2017, but the family had noticed the signs of the disease much earlier. Hallucinations are one of the main features of this form of dementia. The support of their family doctor greatly facilitates family caregivers. To maintain her functional condition, a woman attends physiotherapist classes twice a month. Significant support is provided by neighbours who are aware of the illness and, if necessary, contact family members on weekdays when the woman is left at home alone. So far, help from the municipality has not

been necessary; however, if it is needed in the future, the family will ask for support from the municipal Social Service agency. If the woman's health condition deteriorates, she will be placed in the social care centre 'Lode'. The daughter, who cares for her mother with dementia, notes that emotional support and information about the course of the disease are most needed.

Family caregivers face an extraordinary number of challenges, from negative impacts on their physical and mental health to the expected loss of their relative: 'Sometimes it seems to me that I will soon be confused myself. There are days when I can no longer stand the emotional presence of my mother. I myself need emotional support to endure all this ... I sometimes feel guilty that it happened to my mom, I feel guilty because I didn't notice before that she already had a bad memory' (family No 1 caregiver). Relatives noted in interviews that they often feel guilty that this has happened to their loved ones and that they cannot help a person with dementia regain their previous quality of life and functional abilities. Caring for a person with dementia is emotionally hard work and involves mental strain and emotional stress, which often manifests itself as guilt, anger, pain, helplessness, and a feeling of emptiness, which often leads to burnout. Even a temporary placement of a person with dementia in a care farm would allow family caregivers to relax, arrange some important family activities.

Understanding and support from others is important for families of dementia patients: 'We have great neighbours. We can safely go to work, because we know that if my mother has left the apartment, the neighbours will call and inform. Once my mother felt that neighbours were stealing her water and she called the house manager and complained about it. The house manager informed us, and we knew what to do next. Our neighbours are a great support to us, and we do not hide from them that my mother is ill' (family No 1 caregiver).

If dementia is diagnosed as a disease, families are more likely to receive support from both the family doctors and other care professionals. However, there are often cases where only the symptoms and signs of the dementia have been identified but the disease has not been diagnosed. All family doctors who participate in the study confirm that they have patients with dementia in their practice. In family doctors' practices, there are both patients who have been diagnosed with dementia and those who have symptoms of dementia, but this diagnosis has not been established. Family doctors cite the distance to specialists who can make this diagnosis, as well as the reluctance of relatives, as the main reasons for not having a diagnosis. Dementia patients are elderly, receive an old-age pension and are not eligible for invalidity benefit.

In family No 2, an 84-year-old woman lives with her son and daughter-in-law. She has not been diagnosed with dementia although she has symptoms. The family lives in a private house outside the centre of Rūjiena. The son and his wife are both of working age and working. The son's wife's work is in shifts, she tries to arrange her work schedule so that she is at work when her husband is at home, but this is often impossible. The old woman is often alone at home during the day. She has not been diagnosed with dementia because her family doctor does not see such a need. About 1.5 years ago, the family noticed a change in the woman's behaviour and, taking care of her safety, decided that she should live with her son's family. This woman has disorientation in time and space, memory and cognitive impairment (these symptoms correspond to the fourth stage of the disease). Her daughter-in-law works in a social care centre, where there are also clients with dementia, and the necessary information about the disease is obtained from her colleagues - a social worker and a nurse. The family has not established good contact with the family doctor, they have not sought help from the social service. Relatives turn to their family doctor only if they need to receive a prescription for medication. Daughter-in-law mentioned that her mother-in-law last visited her family doctor about a year ago. Relatives do not want the Social Service agency to be informed that a person with dementia lives in their family. They are worried that they will then be considered a 'crazy' family. Family No 2 would like to have emotional support and a little material help.

In interviews, relatives admitted that the time when people with dementia live in families is now between one and three years. For relatives to be able to live with a person with dementia, support is needed on a daily basis. Relatives admit that now relatives, neighbours, colleagues and friends provide a lot of support - both emotional and informative.

It is very important to get emotional support from others: 'When a friend comes to me and we are together and talking, I will even forget for a moment how difficult it is for me to take care of my mother-in-law. I can tell everything to my friend and then it's easier for me ... Mom doesn't want to go out of the house anywhere, but when my daughter-in-law comes in and talks to her, they both bake a cake together, then I see that mom feels better for a while, and I also feel relaxed because the daughter-in-law spends time with her.' (family No 2 caregiver). To provide quality care to people with dementia, family caregivers themselves need social interaction to regain strength and socialize with other people. Such socialization is like a moment of rest for them and an opportunity to regain strength, improve oneself and improve one's quality of life by temporarily deviating from the daily routine

associated with caring for a person with dementia. In interviews, relatives admitted that the time when people with dementia live in families is now between one and three years. In order for relatives to be able to live with a person with dementia, support is needed on a daily basis. Relatives admit that now relatives, neighbors, colleagues and friends provide a lot of support - both emotional and informative.

Families caring for people with dementia living outside the city have very limited social contacts. Family No. 3 lives in a private house outside the city of Rūjiena (Jeru parish). The house is located on the outskirts and the nearest neighbours are about 1 km away. A person with dementia is a 79-year-old woman who lives with her daughter. Dementia is diagnosed as a disease by a family doctor, not a psychiatrist. The daughter has terminated her employment because she believes she needs to take care of her sick mother. The old woman has severe memory problems, cognitive impairment, disorientation in time and space, a tendency to wander around, she is unable to take care of her own hygiene. She has limited mobility – she uses a rollator. The symptoms correspond to the fifth stage of the disease. The daughter and the mother with dementia have developed a good relationship with the family doctor. The daughter hides her mother's dementia from others. They both attend church on Sundays because the daughter believes that people in the church understand her situation and support her. The daughter has a good cooperation with the family doctor and physiotherapist. She does not want to use the support of the Social Service agency. The daughter would like to receive emotional and informative support, admits that there is a lack of social contacts, but she does not want to receive any kind of support from the neighbours: 'I feel that I need people around me because being here alone with my mother on a daily basis makes my situation even more difficult' (family No 3 caregiver).

Social interactions are equally important for both the person with dementia and family caregivers. In order to provide quality care to a family member with dementia, they themselves need social interaction to regain strength by temporarily deviating from the daily routine associated with caring for a person with dementia.

However, under the influence of stereotypes and prejudices about dementia in the society, family caregivers often hide this diagnosis, isolating themselves from others: 'I am already guilty that my mother has this disease...' (family No 3 caregiver). These prejudices further increase the risk of burnout, which is already high if he or she must take care of his or her family member with dementia alone.

Although the staff tries to find the optimal solution for each situation, it is not easy for families to take

decision to place their family member with dementia in a care institution. To provide support to relatives of a person with dementia, each long-term social care institution in Rūjiena municipality has developed its own approach and is improving it by adapting to the wishes and needs of each family: 'I invite relatives and the client to visit the institution before the placement to see how we work. Relatives are often emotionally tired of a person with dementia care at home. Relatives expect emotional and informative support from us. They also want information about the course and symptoms of the disease. After placement, we allow a relative to visit their loved ones as often as they wish' manager of a private long-term care centre 'Rūjienas senioru māja'). Care institutions try to maintain relationships with the client's family. State social care centre Vidzeme branch 'Rūja' manager: 'I believe that family ties play an important role so that the client, even if placed in a care institution, does not feel lonely and abandoned. Basically, it is regular communication to inform about clients' health, social activities, etc. As far as possible and if relatives are interested in, we explain how the disease affects the client's personality'.

For relatives, placing a person with dementia in a care centre is a difficult and important decision. Relatives try to provide family care as long as possible. Social care farms for people with dementia in care could be a halfway point between the family and the long-term care facility.

Conclusions

Social farming covers at least three dynamic areas of society - rural development, social entrepreneurship and the growing demand for social care services, and it is closely linked to the concept of multifunctional agriculture.

Many European countries have considerable experience in social farming. These are not only countries with strong social welfare systems, but also the new EU member states, similar to Latvia.

Foreign experience shows that social care farms can provide care services to people with early dementia, extending the time when the need arises to place them in long-term care facilities.

Currently in Latvia, families where one of the family members has dementia have only two options – to place their relatives in a care institution or to take care of them in the family. Placement of people with dementia in social care institutions is often the last resort although family caregivers face serious difficulties.

Family composition, living conditions and level of material well-being affect the ability to care for a relative with dementia.

Family caregivers face an extraordinary number of challenges, from negative impacts on their physical

and mental health to the expected loss of their relative. The situation is complicated by the fact that, due to stereotypes and prejudices about dementia in the society, family caregivers often hide this diagnosis in isolation from others.

For relatives, placing a person with dementia in a care centre is a difficult and important decision. Relatives try to provide family care for as long as possible. The services offered by social care farms would significantly improve the care of people with dementia, as they would act as a missing step between the care of these people in families and long-term care institutions.

Working with people with dementia requires holistic support and help – to maintain his social

network, to strengthen his individuality, to give him the ability to self-determination, to inform him, to promote his independence and promote factors that improve his quality of life. Further research is necessary to investigate models of ensuring the quality of social care services for persons with dementia in social care farms, to develop models of financial viability of these farms.

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IMPLEMENTATION OF THE COMPLIANCE SYSTEM IN THE ACTIVITIES OF AGRICULTURAL ENTERPRISES IN UKRAINE: PREREQUISITES AND MAIN ASPECTS

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Abstract

The article defines the prerequisites and main aspects of implementation of the compliance system in activities of agricultural enterprises in Ukraine. It has been established that the compliance system for Ukrainian agricultural enterprises is completely new, and there are practically no procedures for its formation and functioning. Using SWOT analysis matrix, strengths and weaknesses, opportunities and threats of the compliance system for Ukrainian agricultural enterprises have been identified. It has been established that the agricultural business is able to ensure the implementation and operation of the compliance system, which is focused on international compliance values. An algorithm for introducing a compliance system into the activities of agricultural enterprises has been proposed. Its implementation and observance will allow agricultural enterprises to minimize compliance risks, ensure their financial stability and innovative development, increase trust of customers, partners and investors to be competitive both in the domestic market and external one. It has been determined that compliance risk management is a cyclical process, whose main goal should be to minimize the identified risks using the development and implementation of appropriate control procedures and measures. In order to minimize compliance risks arising in the process of relations between agricultural enterprises and counterparties, an organizational model of their management has been proposed. The application of the methodological approaches presented in the model will allow agricultural enterprises to establish working relationships with counterparties, including foreign ones, and in the future to attract foreign capital and investment in their activities.

Key words: compliance system, agricultural enterprises, compliance policy, compliance risk.

Introduction

In the context of integration into the international space and full-fledged membership of Ukraine in the World Trade Organization, the issues of access to the international market for agricultural products, the quality of which must meet the requirements of current legislation, international standards, export competition in agricultural and food trade, are quite acute. In addition, for the effective development of entrepreneurial activity at the international level, Ukrainian agricultural enterprises need to constantly confirm that their activities comply with the established ethical and business standards of doing business in the vector of combating corruption and fraud and managing the risks of the possibility of introducing international sanctions. However, the influence of external factors (political, economic instability, COVID-19) and internal (violation of legislation, business ethics, conflict of interests) significantly increase the level of risky processes in the functioning of agricultural enterprises. All this requires the management of agricultural enterprises to develop mechanisms that minimize the likelihood of not only financial losses, but also loss of confidence on the part of customers in the domestic and international markets, loss of finding international business partners and investors. A comprehensive solution to these tasks can ensure the implementation of a compliance system.

The theoretical and methodological aspects of compliance have been studied in the works of a

significant number of scientists, in particular (Adelina *et al.*, 2020; Bilal & Baig, 2019; Birindelli & Ferretti, 2008; Bovsh & Kulyk, 2020; Fedulova & Piatnytska, 2020; Foorthuis & Bos, 2011; Kalinichenko, 2014; Kobieliyeva, 2019; Kozhina, 2019; Lavrenko, 2020; Ludwick, 2006; Meissner, 2018; Vanni, 2017; Vnukova, 2018; Voloshenko, 2014; Yudina, 2018) *et al.* Their researches are aimed at solving important problems of the development of the compliance system in industrial enterprises and various sectors of the economy, in particular the banking and insurance spheres. At the same time, it should be noted that the issues related to the definition of the basic prerequisites, the development and substantiation of theoretical and methodological approaches to the implementation and formation of a compliance system in the activities of agricultural enterprises in Ukraine require further development.

The goal of scientific articles is to determine the prerequisites and main aspects to develop theoretical and methodological foundations, to substantiate methodological recommendations for the implementation of the compliance system in the activities of agricultural enterprises in Ukraine.

Materials and Methods

The methodological basis of scientific research is the theory of systems, the theory of the development of economic systems, the theory of risk management, the theory of decision-making. When writing the article, general scientific and special methods were

used: abstract-logical (cognition of the essence, prerequisites and features of the implementation of the compliance system in the activities of agricultural enterprises, the formation of conclusions), system analysis (presentation and description of the algorithm of actions for the implementation of the compliance system in the activities of agricultural enterprises), method of SWOT analysis matrix (identification of strengths and weaknesses, as well as opportunities and threats arising in the process of introducing the compliance system into the activities of agricultural enterprises), graphical (design of the described processes using logical algorithms, organizational models).

Results and Discussions

“Compliance” translated from English means accordance, conformity, agreement. Compliance is an institution of the internal control and corporate ideology system, which, using a system of regulations and a set of control mechanisms, forms the company’s ability to comply with established norms, standards, rules and procedures, and also necessarily takes into account the risks accompanying its activities, and with the help of a set of measures eliminates their adverse consequences, as a result of which - ensures the sustainable development of the enterprise.

For agricultural enterprises, in particular Ukrainian ones, the compliance system is quite new, and there is practically no description of the procedures for its formation and functioning in this area. This is

confirmed by a survey devoted to the priorities of the development of the compliance function in Ukraine, the countries of the Commonwealth of Independent States (CIS) and neighboring countries, conducted by KPMG (auditing firm) in Ukraine.

Thus, according to the research, today the oil and gas industry remains an industry where a separate compliance function began to form earlier than anywhere else (Figure 1). This sector is the leader in terms of the number of respondents who have had compliance functions for more than 10 years. The youngest compliance function according to the research results are in companies operating in the field of innovation and technology. As for the enterprises of the agricultural sector of the economy, none of the surveyed respondents used the functions and tools of the compliance system.

In the period 2017–2019, Ukrainian producers were in the top three among the world exporters of agricultural products to the European Union. This fact demonstrates the importance and necessity of their activities in accordance with international compliance values.

We have identified a number of advantages and benefits from the implementation of the compliance system in the activities of agricultural enterprises (Table 1). However, there are weaknesses and threats that hinder the implementation of the compliance system, including: lack of appropriate legislative and regulatory support, insufficient number of specialists, incurring additional costs on the part of the enterprise.

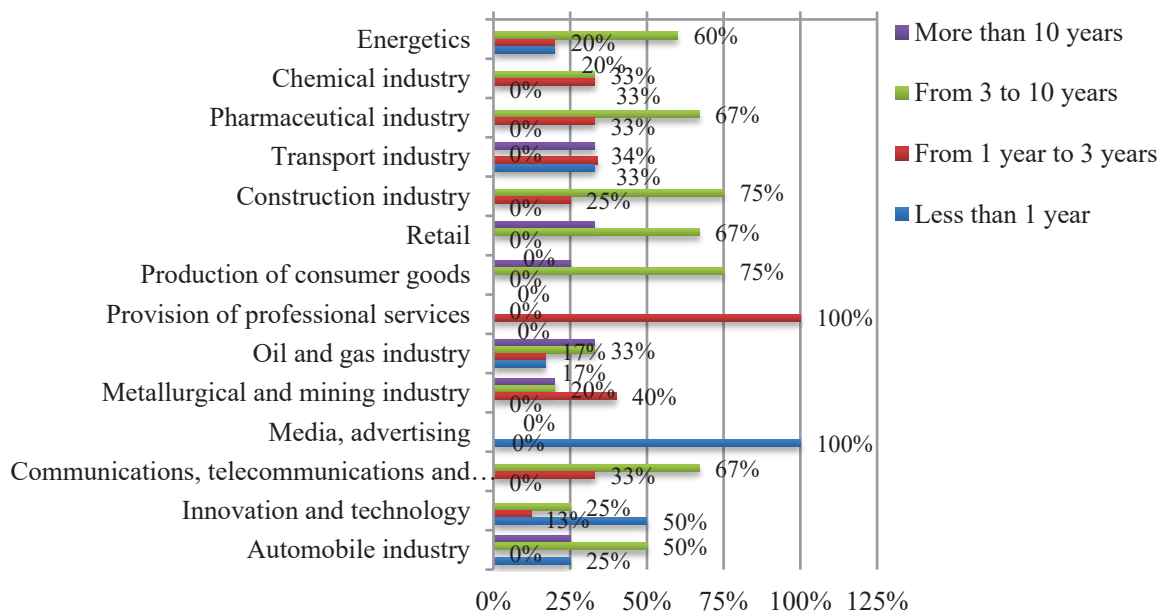


Figure 1. Implementation of the compliance system in the sectors of the economy of the CIS and Post-Soviet Countries, 2020.

Source: (data of KPMG’s survey in Ukraine “Compliance in the CIS and Post-Soviet Countries: Current Issues and Trends, 2020”).

Table 1

SWOT analysis matrix of the implementation of the compliance system in the activities of agricultural enterprises in Ukraine

Strengths	Weaknesses
<ol style="list-style-type: none"> 1. Effective risk management. 2. Protection of business from theft, fraud. 3. Minimization of risks of loss of assets, image. 4. Increasing the level of corporate culture and social responsibility of agricultural enterprises. 5. Increasing consumer confidence in agricultural products in the domestic and external markets. 6. Increasing the profitability and financial stability of the enterprise. 	<ol style="list-style-type: none"> 1. Lack of domestic regulatory framework on compliance issues (except for the banking sector). 2. Insufficient practice of implementation of compliance and, accordingly, dissemination of information about such positive results. 3. Insufficient number of compliance specialists. 4. Additional expenses of the company for the maintenance and operation of the compliance service.
Opportunities	Threats
<ol style="list-style-type: none"> 1. Increase in production volumes of high technology competitive agricultural products. 2. Attracting international investments. 3. Simplification of entering international markets. 4. Growth of economic potential. 5. Obtaining certain tax incentives. 6. Improving relations with contractors. 	<ol style="list-style-type: none"> 1. Disinterest of the management in ensuring the functioning of the compliance system at the enterprise. 2. Resistance from the employees of the enterprise in the implementation of the compliance system. 3. Lack of verification of the effectiveness of the compliance service.

Source: prepared by the authors.

Analysis of opportunities and threats allows us to conclude that, despite the weaknesses and existing difficulties, the agricultural business is undoubtedly an industry that is focused on international compliance values and is able to ensure the implementation and functioning of the compliance system.

The compliance culture must successfully reinforce itself in enterprises, and for this purpose, it is necessary to persuade senior management that compliance is not a cost that should be minimized (Vanni, 2017).

According to Herasymchuk, 2019, for the effectiveness of the compliance system at the

enterprise, it should regulate in detail the following main issues: identification of persons responsible for the operation of the compliance system, effective management of identified risks and implementation of measures in case of violations, determination of ways to implement them.

In our opinion, it is advisable to use the proposed algorithm of actions in order to ensure the implementation of an effective compliance system in the activities of agricultural enterprises (Figure 2).

The introduction of the compliance system should be started with the formation of the compliance policy of the agricultural enterprise. Compliance policy

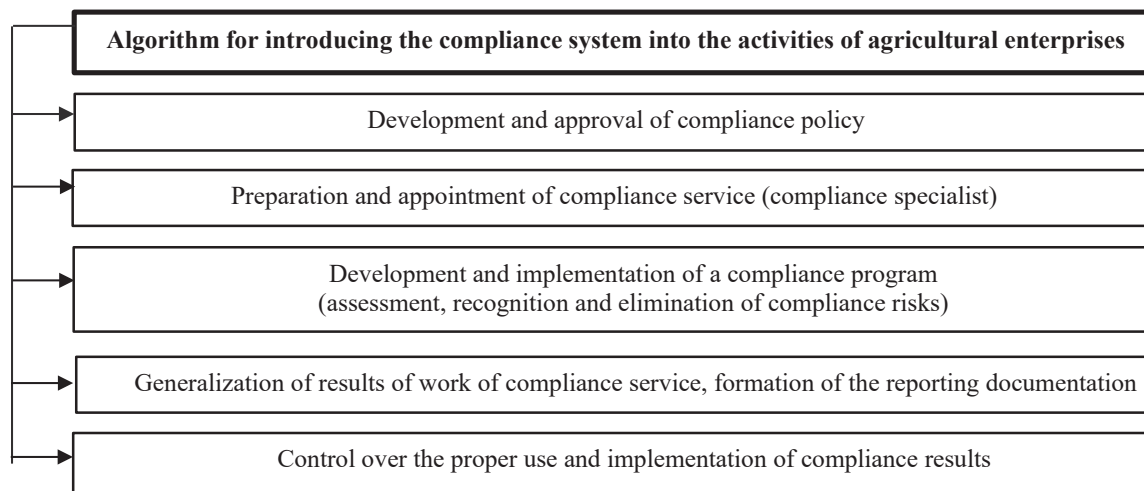


Figure 2. Algorithm for introducing the compliance system into the activities of agricultural enterprises (author's vision).

defines the purpose, objectives of compliance at the enterprise, principles and basic processes.

The objectives of the compliance policy are: creation of an effective compliance risk management system; bringing to the attention of the company's employees, as well as third parties, the basic principles of compliance; prevention of a conflict of interests and the conditions for its occurrence, as well as the possibility of committing crimes and other illegal actions; supporting corporate values and rules, striving to improve corporate culture; ensuring compliance with the principles of open and honest business conduct; ensuring transparency of activities for shareholders, third parties and regulatory bodies; maintaining the business reputation of the enterprise at the appropriate level; achievement of the set strategic goals by the enterprise.

The main task of the compliance policy should be to ensure the formation of an effective system of measures aimed at reducing risks in all areas of the agricultural enterprise, compliance with legislative norms, internal regulations, corporate culture and social responsibility rules.

The issue of ensuring the compliance system at the enterprise should concern all its employees and is a component of its corporate environment. Therefore, the next step should be the appointment and inclusion of the compliance service in its organizational structure (Kobieliieva, 2019):

- on a centralized basis, that is, to create an independent unit that will be fully responsible for the company's compliance activities or appoint a compliance specialist;
- on a decentralized basis, that is, to distribute and delegate compliance functions, for example, between the legal department, audit service, enterprise security service, risk management unit.

The compliance service, as a structural unit of an agricultural enterprise, should be independent of the business goals of the enterprise and must cooperate with other structural units. The duties of the employees of the compliance service or the compliance specialist should be reflected in the developed and approved job descriptions and accounting policies of the enterprise in the context of the activities areas (operational, financial, investment) (Lavrenko, 2020). Compliance service employees must be able to identify, assess, analyze, control and respond positively to compliance risks. Thus, compliance risks are understood as potential or real risks of regulatory sanctions, financial losses, reputational losses that arise as a result of non-compliance with legislation, provisions of internal documents (policies, procedures, regulations, rules), fair competition standards, situations of conflict of interest, non-compliance with requirements of corporate ethics.

The development and implementation of a compliance program at the enterprise is the next step. The main goal of the program may be to ensure effective measures to identify and control risk areas of activity; identification, assessment and minimization of compliance risks. It is minimization that is the goal of managing them, not optimization, because they are characterized by a negative impact on the activities of the enterprise (Vnukova, 2018).

Compliance risk management as an element of the enterprise risk management system is a cyclical process, which includes: identification of compliance risks; assessment of compliance risks; planning of measures of protection against compliance risks; implementation of measures of protection against compliance risks; monitoring and control. That is, it is necessary to manage risks through the implementation of compliance control of business processes (to minimize the likelihood and mitigate the consequences of negative situations, to organize high-quality feedback with market participants) (Bovsh & Kulyk, 2020).

The information base for identifying compliance risks of agricultural enterprises is the process of the agricultural enterprise activity as a whole, expert conclusions of the internal control system divisions, independent audit reports, the results of inspections by regulatory authorities, court decisions, complaints and claims from counterparties, etc.

In our opinion, a prerequisite for the success of the identification of compliance risks in the activities of agricultural enterprises should be the systematic collection, analysis and processing of information from various sources (testing, check lists, questionnaires, appeals in communication channels, the results of extraordinary inspections, etc.). The above will also allow agricultural enterprises to timely and fully identify existing and potential risks, the sources of their occurrence, the consequences of their impact on the activities of the enterprise.

Risks assessment involves determining the degree of probability of their occurrence and possible negative consequences. The most convenient way to assess compliance risks for agricultural enterprises is to assess risks using the method of qualitative assessments and their further minimization. In practice, to carry out such an assessment, it is possible to compile a risk matrix with an appropriate scale of points, developed for each enterprise independently.

So, the main goal of the compliance risk management process should be to minimize the identified risks through the development and implementation of appropriate control procedures and measures (Birindelli & Ferretti, 2008).

Monitoring and control should be the next step in agricultural compliance risk management. Monitoring

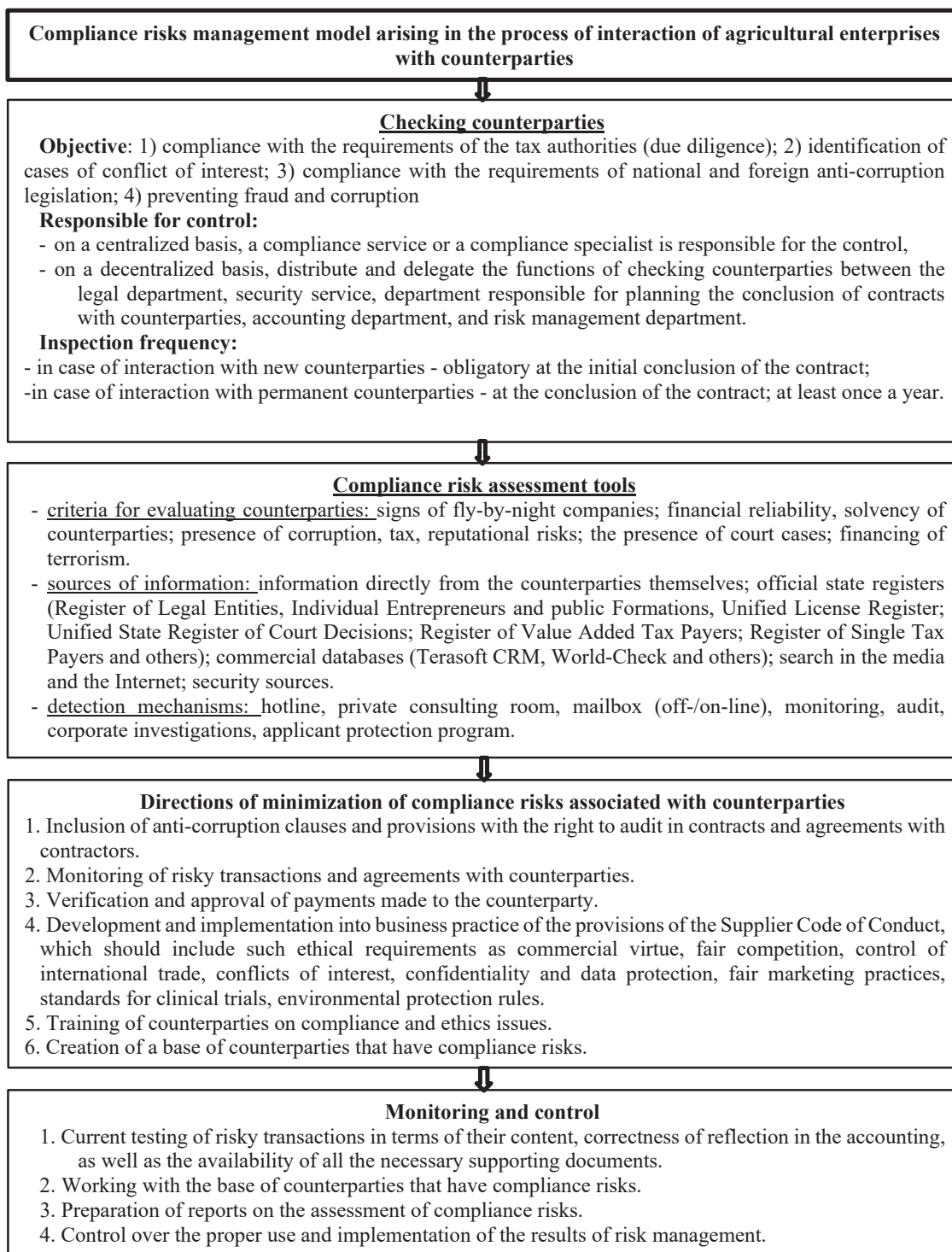


Figure 3. Organizational model of management of compliance risks of agricultural enterprises arising in the process of interaction with counterparties.

contributes to a better understanding of the compliance risk management process, determination of the current level of risk, and its propensity to change. An important aspect of this process is continuous monitoring of the quantitative measurement of compliance risks and trend analysis (Yudina, 2018).

Ludwick, 2006 proposes to create a reporting system on the basis of which the compliance service can identify, track and communicate the risks it faces.

In order to identify and minimize compliance risks arising in the process of interaction of agricultural enterprises with counterparties, we

proposed an organizational model for managing such risks (Figure 3).

The proposed model for managing compliance risks that arise in the process of relationships with counterparties will allow agricultural enterprises of Ukraine to minimize risks, establish reliable and effective working relationships with foreign counterparties, and in the future, attract foreign capital and investments into their activities for its own development.

Conclusions

1. The introduction of the compliance system, as an institution of the internal control and corporate ideology system, into the activities of agricultural enterprises in Ukraine will contribute to:
 - ensuring financial stability and innovative development of enterprises;
 - improving reputation, increasing trust from customers, partners and investors, especially foreign ones;
 - protection against threats and risks associated with violation of approved norms and standards;
 - increasing the level of social responsibility of enterprises.
2. The construction of a SWOT analysis matrix for the implementation of the compliance system in the activities of agricultural enterprises in Ukraine made it possible to identify its strengths and identify opportunities. Weaknesses and existing threats are not an obstacle for the agricultural

business to focus on international compliance values, since this is an industry that is able to ensure the implementation and functioning of the compliance system.

3. To implement the compliance system in the activities of agricultural enterprises, it is advisable to use a certain algorithm, which provides for the development and implementation of a compliance program, preparation and appointment of a compliance service, management of compliance risks, generation of reporting documentation, control over the proper use and implementation of compliance results.
4. Compliance risk management, as an element of the enterprise risk management system, is a cyclical process that involves the identification and assessment of compliance risks, planning and implementation of measures of protection against compliance risks, monitoring and control. The main goal of the compliance risk management process should be to minimize the identified risks through the development and implementation of appropriate control procedures and activities.
5. Using the proposed model for managing compliance risks that arise in the process of relationships with counterparties will allow agricultural enterprises of Ukraine to minimize these risks. The latter can only be a positive prerequisite for further cooperation of agricultural enterprises with foreign and domestic partners and the development of their activities.

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REMOTE JOB DESIGN POSSIBILITIES TO WORK IN LITHUANIAN COMPANIES FROM DISTANT LOCATIONS



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Abstract

The study examines literature on remote job design possibilities from distant locations. After the remote job design concept is formed, the premises for the use of remote job design are analysed, the necessary conditions, possibilities, and employees' willingness to work remotely are explained, summarizing the advantages and disadvantages of remote work. The quantitative research was conducted to reveal out the possibilities of remote job design in Lithuanian companies according to the areas of work in which it is possible, impossible to work remotely or possible to work flexibly. The willingness to do remote jobs was also examined, and the picture of prone to remote job employee by demographic characteristics of the respondents was drawn. The most convenient distant locations, informational and communication technologies (ICT) and addresses of indirect communication were identified. It was found that survey participants are not resistant to work remotely, and it also showed that at least partially remote job could be designed in majority of Lithuanian companies. Most of them prefer flexible mixed variation of remote and traditional work. The main difficulties were named that required high level of self-discipline, but not the lack or deficiencies in using ICT, electronic devices and designing other required conditions for remote job design.

Key words: job design, remote work, distant locations, Lithuanian companies.

Introduction

The trends of globalization, growth, and acceleration of quality of life, emergence of knowledge society and economy, growth of population mobility and evolution of informational and communication technologies (ICT) lead to the emergence of remote job design concept. These days the pandemic situation is fostering remoteness of jobs over the world.

Remote job design reveals its benefits in a global environment, where it is possible to work remotely in the same country, as well as to successfully collaborate with foreign companies from distant locations using ICT. Remote job design enables an organization to hire the best professionals and global talents regardless of where they live. Remote job design is also useful for developing activities in another country without living there. As technology for the transfer of required information speeds up, more attention can be paid to reduce the cost to both employers and employees and increase benefits from innovations in possible remoteness of operations. In order to solve the problems of geographical distance, avoid high costs and save time for the company's employees, companies have to be flexible, use ICT and take advantage of the remote job design.

Before the pandemic Covid-19 situation, Gallup (2017) report stated that about 37% workforce in the USA worked remotely. According to Eurofund (2017), 17% of employees worked remotely in the EU, with Denmark having the highest number of teleworkers (37%). In Lithuania, only about 13% of workforce worked remotely, and the highest prevalence of such workers is recorded in the telecommunications and information technology services sector. According to a Cvmarket.lt (2017), 60% employees in Lithuania showed willingness to work remotely and only 13%

did not want remote work because they liked to go out and be in the society. During the pandemic, 61% workers were given the opportunity to work remotely, and only 34% workers indicated that the nature of their job did not allow them to work remotely (Kantar, 2020).

It is interesting to acknowledge what possibilities are to transfer jobs to a distance without compromising the performance of job functions, which during the pandemic could have been ignored due to the need to keep distance and avoid contact. The question also arises what proportion of the jobs may be at least partially remote or are not suitable for remote job design, and what part of jobs have opportunities to work from a distant location in the future. In order to design remote jobs in Lithuanian companies, it is necessary to find out the current perception of the benefits of remote work and its use in Lithuanian companies. The current situation or expectations may differ depending on the field of work, the size of the company, the position held in the company, the gender and age group of the employees of the companies.

Existing knowledge on remote job design can be questioned in an extraordinary pandemic context. Recently a number of studies analyse remote work, telework, telecommuting (Choudhury, Foroughi, & Larson, 2021; Wang *et al.*, 2021; Gallacher & Hossain, 2020; Gigi & Sangeetha, 2020; Walenetek, 2020; da Silva Abbad *et al.*, 2019; Charalampous *et al.*, 2019; Kaduk *et al.*, 2019; etc.), but still there is a lack of studies relating remote job design to possibilities of work from distant locations. Due to the mentioned reasons, further research is needed to solve the research problem - what are possibilities of remote job design in Lithuanian companies working from distant locations? Thus, the object of the research is remote

job design in Lithuanian companies from distant locations, and the aim of the research is to analyse the possibilities of remote job design in Lithuanian companies from distant locations. To achieve this goal, the following objectives have been set: (1) to perform the analysis of scientific literature on remote job design; (2) to analyse the possibilities of remote job design in Lithuanian companies from distant locations by conducting an empirical research.

Research methods used in the paper are analysis of the scientific literature and quantitative method of survey.

Materials and Methods

With the advent of telecommunication, internet technologies, and increased knowledge work, organizational leaders should question the old, hierarchical notion of job design (Greve & Salaff, 2008). Remote work leads to a new form of job design in which task settings work differently. Due to certain opportunities of globalization and innovations, modern organization has more opportunities to work remotely.

The variety of terminology describing work in a distance from the workplace, the great variety of definitions of remote work in the scientific literature make it difficult to examine the problem of remote work. Still, it was found as a broader term comparing to telework (performed by ICT but could be from traditional office) or telecommuting (from a distant location, but not necessary by ICT). Nevertheless, based on the analysis of the scientific literature, the essential features of this form of work organization have been identified. In all definitions of remote work (Konradt, Schmook, & Malecke, 2000; Fonner & Roloff, 2010, etc.) common features could be found: (1) the dispersion of the geographical location of the members of the organization, (2) lack of face-to-face communication, and (3) the dependence on electronic devices and ICT. The classification of the ways to design remote job allows to be broken down into types according to the place of work, time allocation and intensity of use (Grinceviciene, 2020). Similarly, Haddon & Brynin (2005) point out that remote work is not a homogeneous derivative, and therefore it is necessary to design it by the individual elements of diversity of workplace, time, and scope. For clarity, Gajendran & Harrison (2012) and Perez Perez, Sanchez & de-Luis (2003) describe the intensity of remote work use in terms of periodicity, distinguishing between full-time, partial, and ad hoc remote work. Though, Garrett & Danziger (2007) divide work locations into three categories: (1) flexible work in the office and at home, (2) work at a fixed location (home or other scheduled in employment contract location), or (3) mobile work when working in an undetermined place of work (traveling, hotels, etc.).

As remote job could be designed only using ICT (Grinceviciene, 2020; Walentek, 2020), many scholars list commonly used e-communication channels: e-mail, video, and audio conferences (meetings), messages, forums, specific software, etc. (Karis, Wildman, & Mane, 2016).

Many benefits of remote work from the employee's point of view make it possible to design in the companies (Grinceviciene, 2020; Walentek, 2020; Choudhury, Foroughi & Larson, 2021; (Morganson *et al.*, 2010; Gigi & Sangeetha, 2020; Avdeeva, Davydova, & Shulgin, 2020): the possibility to earn higher salary working for high salaried country's company, to save time and money due to the elimination of commuting and business trips, the possibility of living in a place far away from the company's base, flexibility of work named work-from-anywhere, flexibility in scheduling work, less stress and more comfortable working conditions, high level of work-life balance support, and greater employees' job satisfaction.

Designing of remote jobs for the companies would reduce the company's operating and real estate costs (Choudhury, Foroughi, & Larson, 2021), lead to increased productivity (Gajendran & Harrison, 2012), retain good employees when their living conditions change, and hire the best professionals (Duoba, 2009), encourage knowledge-based working by ICT and then receive a higher income (Sarkiuonaite & Gaputiene, 2006).

Nevertheless, many scholars argue that remote workers recognized less decision-making autonomy, task variety, task significance, task identity, job complexity, problem solving, and specialization than the traditional employees (da Silva Abbad *et al.*, 2019), experienced threats in professional advancement (Charalampous *et al.*, 2019), over-working and a lack of time for recuperation (Grant, Wallace, & Spurgeon, 2013), work-home interference, ineffective communication, procrastination, and loneliness (Wang *et al.*, 2021), a sense of social exclusion (Gibson & Gibbs, 2006), ambiguous perception of information by ICT (Derks & Bakker, 2010), lack of nonverbal behaviour related to different national language, culture and technologies (Duarte & Snyder, 2006).

One more issue concerning remote job design is the legal status of remote work. When companies have been calling employees back to the office, some employees are therefore asking to continue remote arrangements their employers adopted when forced to close. Should an employer refuse, the affected employee will have to balance legitimate fears for safety and job (Arnaw-Richman, 2020). This differentiation between voluntary and forced scheduling and remote work underlines the complexity of flexible scheduling and remote work, especially among white-collar, salaried professionals (Kaduk *et al.*, 2019).

Implementing remote job design, planning and thorough scientific analysis should be performed. In order to determine the possibility of remote job design in a company, it is necessary to answer important questions about geographical location, interdependence of companies, company's uniqueness, competencies, level of trust and use of ICT in the company (Duoba & Savaneviciene, 2010). Benefits and barriers should be considered as well, leveraging the right level and mode of remote job design in particular circumstances.

Many managers are afraid to lose control and diminish organizational capacity for innovation due to decreased collaboration (Calvo, 2010). Managers must be trained to maintain remote working relationships and secure productivity (Calvo, 2010). Formulation of work goals, adaptation, and motivation of remote employees improve communication between employees (Sarkiunaite, 2009). Trust and management style were found to be key influences on remote worker effectiveness (Grant, Wallace & Spurgeon, 2013). Remote work candidates should be selected through psychometrically validated criteria. After all, remote workers must be assessed fairly and objectively on the accomplishment of their work (Calvo, 2010). Both readiness from employer and employee are considered as the main factors to implement remote job design in the companies successfully (Duarte & Snyder, 2006).

Methods

Quantitative research was chosen for data collection, which aims to obtain quantitative information about a large number of research objects (in this case, persons working in Lithuanian companies). The research questionnaire consists of an introductory part, demographic questions, and questions about features, preferences, extent, and possibilities of virtual job design in the companies. Willingness and ability to work in remote locations, the application of remote job design according to the respondents' field of occupation, commuting and other costs, as well as benefits and barriers (in scale from 1 to 3) when working remotely were screened.

The research sample was calculated on the basis of Paniotto formula (Kardelis, 2002). According to the data of the Department of Statistics of Lithuania,

in the 3rd quarter of 2019, there were 1378.1 thousand persons who were working in any job and receiving remuneration in money). The selected sample error size is 7%. Calculations show that 204 respondents need to be interviewed to ensure the representativeness and reliability of the survey, the survey involved 211 respondents working in various Lithuanian organizations; therefore, it can be stated that the results of the survey are reliable.

Participants were sent an invitation e-mail with a link to fill the online questionnaire.

66.4% of respondents were woman and 33.6% – men; 69.7% are 16-25 years old, 23.7% – 26-35, and 4.3% – 36-45, 1.9% – 46-55, and 0.5% is older than 56 respectively; 17.5% are working in sales, 11.8% – service, 9% – marketing/advertising, 8.1% – production, 7.1% – culture/arts/entertainment, 7.1% – tourism/catering. 15.6% were employers/entrepreneurs, 8,1% – self-employed, and 76.3% – employees; 33.6% work in micro-enterprises, 29.4% – small, 19.9% – large, the rest – in medium-sized companies.

The obtained data were analysed through the SPSS 21 software. Descriptive statistics and crosstabulation were used for data analysis. The reliability of the questionnaire was screened using Cronbach's alpha coefficient using the SPSS program, varied from 0.648 to 0.683, confirming strong compatibility of the instrument used.

Results and Discussion

Primarily the segment of jobs where it was possible for the respondents to perform their job duties remotely was identified: 37.9% of survey participants estimated that their work could not be done in a remote way, but 26.1% of respondents job duties cannot be performed remotely. Other respondents estimate that the part of work could be done remotely and the other part – in a workplace created by employer. Thus, it can be stated that the majority of respondents (62.1% in sum) could perform at least part of their job duties working remotely.

Nevertheless, 26.1% jobs can be fully remote, only 4% of respondents prefer to have completely remote job. The majority of respondents (41.2%) would like to have the opportunity to mix working from home

Table 1

Comparison of possible and preferred remote job design, %

	Possible	Preferred
Yes, 100% remotely	26	4
70% remote/30% traditional	4	11
50% remote/50% traditional	14	48
30% remote/70% traditional	10	22
No, 0% of remote work	38	15

Table 2

Possibility of virtual job design by fields, %

Finance/Accounting	67	Marketing/Advertising	42	Service industry	12
Education/Science	67	Agriculture/Environment	40	Manufacturing/Industry	12
IT/Electronics	60	Law/Legal Aid	25	Administration	8
Public Relations	57	Management	20	State and public administration	0
Transport/Logistics	57	Construction/Real Estate	17	Security/Rescue/Defence	0
Telecommunications	50	Trade/Sales	14	Human resources	0
Culture/Arts/Entertainment	47	Tourism/Hotels/Catering	13		

Table 3

The willingness of the study participants to work remotely according to age groups, %

Age group	No willingness	Partly remotely	Flexibly remotely	Fully remotely	Work remotely
16-25	15	17	43.5	15.6	8.8
26-35	14	20	34	12	20
36-45	33.3	0	44.4	11.1	11.1
46-55	25	50	25	0	0
56 and more	0	0	100	0	0

with going to workplace in flexible way (Table 1), 15.6% – would not like to, and 14.2% – would like to have remote job. 17.5% want to work remotely occasionally, 11.4% currently have remote job place.

The crosstabulation of the data reveals that the majority of the jobs impossible to perform remotely are in service (11.8%) and trade/sales fields (17.5%). Only 3 respondents from the service industry and 5 working in trade/sales state that it is possible to perform job duties from a distance and several respondents believe that it is possible to perform work duties in mixed way.

According to those working in finance/accounting, education/science, information technology/electronics, public relations, transport/logistics, telecommunications, culture/arts/entertainment, marketing/advertising, agriculture/environment, it is possible to perform their job duties from distant locations in general. Only in fields of state and public administration, security/rescue/defence, and human resources it is not possible to work remotely (Table 2):

Respondents used to be working from remote locations: 5 respondents from marketing/advertising, 4 – from culture/arts/entertainment, 4 – from

public relations, 4 – from trade/sales, 1 – from finance/accounting, 1 respondent each was in IT/electronics, services, construction/real estate, health/social security, education/science, and agriculture/environment fields.

Depending on the age distribution of the respondents, only respondents from the 16-25, 26-35, and 36-45 years old groups have remote work experience. Of these, participants of 16-25 years old are the most willing to work from distant locations, while 46 years old and older respondents are much less impressed by the possibility to work remotely (Table 3):

Table 4 analyses the willingness to work remotely by gender: perhaps in need of flexibility performing other duties in personal life and striving for work-life balance, women appear to be more willing to work remotely in flexible way than men, which would prefer more a 100% remote job.

Also, the willingness to work remotely was analysed by the position held by employees in the company. In the employers/shareholders/self-employed group willingness to work fully remotely is higher (23.5%) than employees (15.6%), and 23.5%

Table 4

Willingness to work remotely by gender, %

Gender	No willingness	Partly remotely	Flexibly remotely	Fully remotely	Work remotely
Women	8.6	20	44.3	11.4	15.7
Men	16.9	12.7	35.2	19.7	15.5

Table 5

Direct/indirect communication throughout the working day with colleagues/managers and clients, %

	With colleagues/managers	With clients
Indirect only	6.6	15.2
Indirect most of the time	9.5	16.6
50% indirect, 50% direct	17.5	17.5
Direct most of the time	38.4	23.7
Direct only	28.0	27.0

Table 6

Encountering remote job design by the size of the company, %

	Micro-size	Small	Medium	Large
Communicating with managers/colleagues/clients abroad	42.3	25.8	33.3	35.7
Communicating with managers/colleagues/clients in Lithuania	54.9	43.5	41.7	54.8
Cooperating with partners or suppliers operating abroad	36.6	25.8	19.4	23.8
Cooperating with partners or suppliers operating in Lithuania	49.3	45.2	33.3	35.7

of employers/shareholders/self-employed are used to work remotely all the time, while only 11.4% of employees do the same. The employers/shareholders/self-employed are less willing to work in mixed flexible way (23.5%) when compared with employees (41.2%).

In sum, the picture of prone to remote job employee by demographic characteristics of the respondents can be drawn: (1) man, (2) 16-25 years of age, (3) freelancer /working in small company, and (4) working in sales or marketing area.

If survey participants are given the opportunity to work remotely from distant locations, the largest part (62.1%) will work from home, 41.7% – flexibly from anywhere and anytime, 25.1% – when traveling, 12.8% agree to work remotely during vacation, 1.4% will find suitable public place, and only 0.9% of respondents find possible to combine several remote occupations, i.e., to get a higher salary. 15.6% – do not want to work remotely, but only 3.3% of them will not categorically work remotely. So, it can be argued that, by getting acquainted with the remote work model, companies start to see the benefits and design remote workplaces, as there is no strong opposition to remote job design.

Assessing the use of indirect communication channels used in companies when working, in communication with colleagues and managers most respondents use telephone (86.3% of respondents), e-mail (70.1%), messages (32.7%), specific software (32.2%), video conferencing (17.1%), so, remote job design for them would not be an obstacle to communicate, but 32.2% of respondents communicate with managers and colleagues only directly face-to-face.

When compared, more respondents interact indirectly with clients than with colleagues or managers at work. Most respondents communicate only a small part of their working time indirectly with colleagues/managers (38.4% of respondents) (Table 5), and the smallest part of respondents do not have any direct contact with colleagues/managers during work (6.6%). Many respondents (27%) communicate with customers only directly at the workplace and 23.7% – have a small part of indirect communication with clients.

Explaining where the respondents face the conditions of remote job (Figure 10), 49.3% face it when communicating with managers/colleagues/clients living in another Lithuanian city, fewer (42.7%) – in cooperation with partners or suppliers operating in Lithuania, 34.6% communicates with managers/colleagues/clients working abroad, and 28.0% cooperate with other companies or suppliers abroad. It shows the availability of remote job design even working with inner market, as well as it can help to reduce the cost of business trips abroad.

Analysing remote job design considering the size of the company, it can be stated that indirect communication with managers/colleagues/clients/partners/suppliers from another Lithuanian city or abroad is most relevant for small companies when compared to large ones (Table 6). Thus, remote job design can be suggested firstly for smaller companies in order to assure all needed infrastructure and help of professionals they cannot afford to hire at the moment.

The most acceptable remote work schedule for survey participants is flexible one, when employee can choose the right ratio of remote work to traditional

working hours (47.4%). The lowest number of survey participants (4.3%) was in favour of all 8 hours of remote work, as well as only 14.7% would like to work all 8 working hours at the employers' guaranteed workplace. 22.3% of the respondents would work virtually less of their working time, while 11.4% would work most of their working hours from distant location. Therefore, it can be argued that flexible remote job design could be implemented in the majority of companies in order to reduce costs and raise job satisfaction, as well as employer attractiveness.

However, most of the participants agreed with the statement that the results of working remotely depend on self-discipline (2.66 points from 3) and that it would be useful to develop remote jobs in distant locations (2.38 from 3), especially when the lower costs (2.23 from 3) and convenience avoiding commuting (2.22 from 3) are considered. Most of the respondents does not avoid the use of indirect modern ways of communication (2.10 from 3), they even feel less stressed when the formal communication and clothing style is not remotely needed (2.09 from 3) and feel less tension and competition between team members (2.02 from 3).

The main benefits of remote job design identified by respondents are: workplace cost savings (71.6%), savings in money and time (71.1% and 67.3% respectively), convenience (57.3%), although the promotion of new opportunities/innovations in companies and the growth of mobility (37.4% and 39.8% respectively), quick response in the process (29.9%), faster information transfer (24.2%), personal development (23.7%), efficiency (15.6%), accuracy and clarity of information (11.8%) are not considered as strengths of remote job design.

Barriers to remote job design appeared to be quite low: difficulties to concentrate (for 30% of respondents), the need for direct contact with both clients (36.0%) and colleagues (28.0%), difficulties to understand the information (21.8%), lack of experience (27.0%), only 16.1% named the hostile attitude of the managers against remote job in Lithuanian companies, as well as insignificance of factors related to internet connection, working with ICT and e-devices is revealed.

Conclusions

The most important factors determining the emergence of remote job design are globalization,

growth, and acceleration of quality of life, emergence of knowledge society and economy, growth of population mobility and evolution of information and communication technologies. The characteristics of remote job design differ from traditional work in the form of cooperation and workplace, but there are also similarities: the pursuit of organizational goals, communication (indirect) to perform the task correctly, organizational attitudes and more than one working individual.

The employees of Lithuanian companies recognize the benefits of remote job design and would like to work remotely in flexible way for the most, where and when it is needed, at least in a part of their work time. Nevertheless, it is believed that in some areas remote job design application is completely impossible.

Managers in Lithuanian companies do not oppose remote job design, but when working remotely it would be difficult to concentrate and communicate with clients or colleagues and maintain fulfilment of social needs at work; therefore, initial actions on remote job coordination systems and preparing as well as motivating employees to perform work in a timely and productive manner are essential. This would lead them to greater operational efficiency. The remote job design in Lithuanian companies would encourage the implementation of innovations, modernization of workplaces in Lithuania, which would be cheaper and more convenient for the companies and their employees.

Remote job design reveals its benefits in a global environment, where it is possible to work remotely in the same country, as well as successfully collaborate with foreign companies using ICT. Remote workplaces enable companies to hire the best professionals as global talents regardless of where they live. Remote work is also useful for developing business activities in other country without living there. As technology speeds up the transfer of required information, more attention can be paid to reduce the cost of commuting to employers and employees. Remote job design in Lithuanian companies would be effective in terms of cost reduction and employee convenience, as well as useful in cooperation with foreign companies or partners in different cultures. Thus, flexible remote job should be seen not as an exception for the members of the organization, but as reducing costs in the company, increasing the productivity of the organization and job satisfaction of employees.

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EVALUATION OF SUSTAINABLE DEVELOPMENT OF ENTERPRISES IN THE DIGITAL TRANSFORMATIONS

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Abstract

In the context of digital transformations, the development of telecommunications enterprises is one of the basic conditions for the digitalization of the country's economy. The paper developed a mechanism for assessing the effectiveness of sustainable development of a telecommunications enterprise, based on the principles of constructing neural networks by assessing the economic, environmental and social subsystems of the enterprise. The mechanism is a set of analytical, evaluative and resulting blocks, the key link of which is to determine the multiplier of the effectiveness of balanced development based on the calculation of indicators of economic, social, environmental and institutional subsystems of external and internal development in order to form a triune strategy for concretizing potential opportunities in the context of digital transformations and its application as a correction factor in assessing the business value of a telecommunications company.

Key words: balanced development, telecommunication enterprise, digital transformation, efficiency, multiplier.

Introduction

Nowadays, there is a significant amount of scientific research on the organization and development of the information and communication technologies (ICT) market. In the monograph (Steklov, Kostik, & Berkman, 2005) the principles of building modern control systems in telecommunications are considered, the presented modern control systems are implemented and the economic efficiency from its implementation is assessed. In scientific works (Vorobienko & Granaturov, 2011; Granaturov, 2009; Granaturov & Vorobienko, 2009), the problems of using the patterns of ICT influence on the economic development of the country have been identified and methodological and methodological tools have been developed for analyzing the competitiveness of telecommunications services. The impact of information and communication technologies (Iscan, 2012), as well as broadband internet on the economy and economic growth of the country is considered (Katz, 2012). A study of rural communities in India, Mozambique and Tanzania (Souter *et al.*, 2005) was conducted to identify the economic impact of telecommunications on agriculture and poverty reduction. The development of information and telecommunication technologies in the "ICT for development value chain" is considered based on indicators of vulnerability and accessibility of ICT (Heeks, 2010); the impact of the American wireless telecommunications industry on the US economy (Entner & Lewin, 2010). The components of ensuring effective regulation of the modern services market (Orlov *et al.*, 2011), the process of information assets of enterprises in the field of telecommunications (Redkin & Koval, 2007), market mechanisms and structures

of the economy of information and communication services (Striy, Zaharchenko, & Golubev, 2014) have been analyzed, shows the importance of marketing strategies in the field of telecommunications (Khrushch & Koran, 2011); substantiated the need to reorient telecommunications companies to a new sustainable type of development (Kniazieva & Doysan-Korovenkova, 2015; Kniazieva & Kalugina, 2015), as well as the factors that necessitate the transition of a telecommunications company to new forms of marketing communication channels and provide the main types of effect that can be obtained (Maslii *et al.*, 2017; Demianchuk *et al.*, 2021). At the same time, the analysis of scientific literature made it possible to reveal that among the numerous scientific works in the context of digital transformations, special attention should be paid to the development of a mechanism for evaluating the effectiveness of the balanced development of telecommunications enterprises, which is the purpose of the work.

Materials and Methods

The conceptual and methodological basis of the work is formed by scientists specializing in the theory and practice of sustainable development of enterprises. The study is based on a set of general scientific and special methods of cognition of the theoretical, methodological and conceptual foundations of the balanced development of a telecommunications enterprise, in particular, for developing a mechanism for evaluating the effectiveness of balanced development of telecommunications enterprises, process and synergetic approaches with elements of neural network modeling, methods of optimization, formalization, factor analysis and simulation were used.

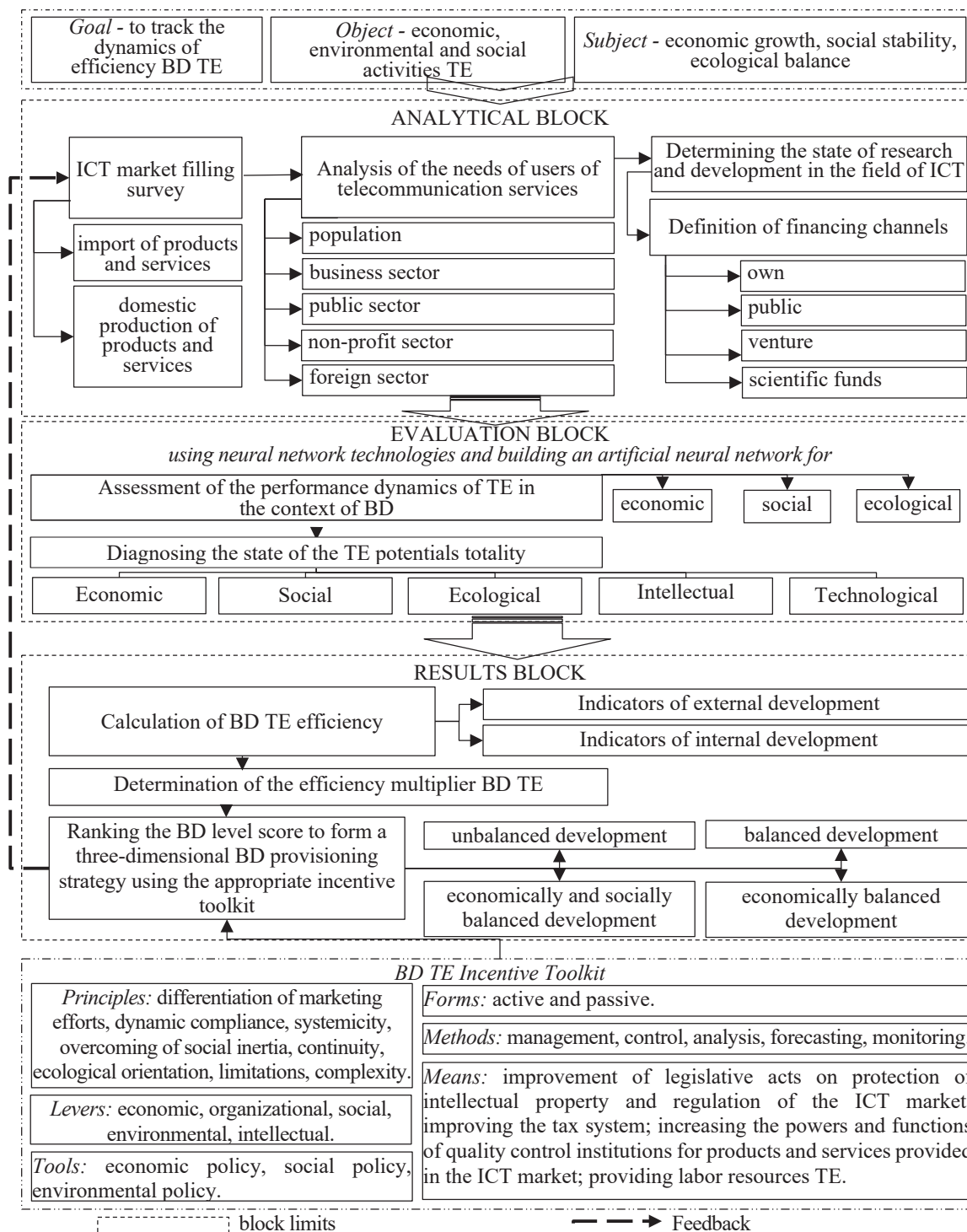


Figure 1. Efficiency evaluation mechanism balanced development of a telecommunications enterprise. Source: constructed by the authors.

Results and Discussion

In the research, developed efficiency evaluation mechanism of balanced development of a telecommunications enterprise is shown in Figure 1. The main purpose of the mechanism is to track the dynamics of the effectiveness of a balanced

development (BD) of a telecommunications enterprise (TE) (BD TE).

The developed mechanism consists of three blocks: analytical, evaluative and resulting. The first analytical block is responsible, firstly, for the survey of the content of the ICT market with the determination

Table 1

Indicators of internal balanced development of a telecommunications enterprise

№	Name and essence of indicators	Calculation formula
1.1.	<i>Indicators of the economic subsystem</i> are based on funds (C'_e) that were spent on measures for economic development	
1.1.1.	The financial stability shows the change in the financial condition of a telecommunications company (ΔK_{fs})	$D'_{1.1} = \frac{\Delta K_{fs}}{C'_e}$.
1.1.2.	The activity profitable dynamics shows the change in the profitability of the economic activity of a telecommunications enterprise (ΔK_p)	$D'_{1.2} = \frac{\Delta K_p}{C'_e}$.
1.1.3.	The equality of the tax burden of the enterprise's activities to the measures of the economic development of the enterprise is calculated as the change in the tax burden (ΔK_t)	$D'_{1.3} = \frac{\Delta K_t}{C'_e}$.
1.2.	<i>The indicators of the social subsystem</i> take into account intellectuality and digital sufficiency of the employees of the enterprise, as well as the complexity of their social support, taking into account the funds (C'_s) that were spent on social development activities	
1.2.1.	The intellectuality of the staff of a telecommunications enterprise provides a dynamic change in the level of intellectuality of enterprise (ΔK_i)	$D'_{2.1} = \frac{\Delta K_i}{C'_s}$.
1.2.2.	Digital sufficiency of personnel demonstrates the development of digital competencies of employees of a telecommunications enterprise (ΔK_d)	$D'_{2.2} = \frac{\Delta K_d}{C'_s}$.
1.2.3.	The complexity of social support for staff is characterized by a change in the level of provision of social infrastructure to meet the social, domestic and cultural needs of employees (ΔK_s)	$D'_{2.3} = \frac{\Delta K_s}{C'_s}$.
1.3.	<i>The indicators of the ecological subsystem</i> reflect the energy efficiency, the safety of work, the pollution track of the enterprise, taking into account funds (C'_{ec}) that were spent on environmental development measures	
1.3.1.	Energy efficiency reveals improvements in the consumption of energy resources in the activities of a telecommunications enterprise (ΔK_e)	$D'_{3.1} = \frac{\Delta K_e}{C'_{ec}}$.
1.3.2.	The safety of work is calculated as a change in the working conditions of employees of a telecommunications company (ΔK_w)	$D'_{3.2} = \frac{\Delta K_w}{C'_{ec}}$.
1.3.3.	The pollution track of operation shows the change in the level of emissions (ΔK_h)	$D'_{3.3} = \frac{\Delta K_h}{C'_{ec}}$.
1.4.	<i>The indicators of the institutional subsystem</i> expose the concentration of the system, the coherence of management actions and the sensitivity of the quality of the services provided, taking into account the funds (C'_{in}) that were spent on measures for the institutional development of the enterprise	
1.4.1.	The concentration of the system demonstrates the effectiveness of the existing organizational structure (ΔK_o) with the changes over time	$D'_{4.1} = \frac{\Delta K_o}{C'_{in}}$.
1.4.2.	The consistency of management actions expresses the change in the effectiveness of the management actions taken to develop the activities of an enterprise (ΔK_c)	$D'_{4.2} = \frac{\Delta K_c}{C'_{in}}$.
1.4.3.	The sensitivity of the quality of telecommunications services is calculated as the ratio of the difference in the quality of services (ΔK_q) in the current and previous periods	$D'_{4.3} = \frac{\Delta K_q}{C'_{in}}$.

Source: constructed by the authors.

of the volume of domestic production of goods and services and imported ones. Secondly, the needs of users of telecommunications services, highlighting such segments as the population, business, government non-profit and foreign sectors are analyzed. This segmentation of telecommunications consumers will allow the most detailed study of needs, determine the demand for existing services and establish the potential demand for innovative

products and services. It will also allow for measures to stimulate or create demand for these products and services. Thirdly, clarification of researches in the field of ICT makes it possible to assess developments in order to understand the needs and potential demand of consumers of telecommunications services. At the same time, it is also advisable to determine the financing channels (state, venture, scientific funds) in order to establish the level of commercialization of

research and find out amounts of financial resources for the plans implementation.

The second evaluation block evaluates the dynamics of the effectiveness of the economic, social and environmental activities of a telecommunications enterprise, as well as diagnosing the state of the totality of its economic, social, environmental, intellectual and technological potential. It is advisable to carry out

the assessment and diagnosis processes using neural technologies and building an artificial neural network (Demianchuk, 2020).

The third resulting block is aimed at calculating the efficiency of the BD TE based on indicators of internal and external development, ranking the assessment of the BD TE level based on determining the TE efficiency multiplier in order to use it as a

Table 2

Indicators of external balanced development of a telecommunications enterprise

No	Name and essence of indicators	Calculation formula
2.1.	<i>Indicators of the economic subsystem</i> reflect the concentration, manufacturability and diversification of an enterprise in the telecommunications services market, taking into account funds (C''_e) that were spent on measures for economic development	
2.1.1.	The concentration of an enterprise on the telecommunications services market determines the change in the market share occupied by a telecommunications company (ΔK_{mc})	$D''_{1.1} = \frac{\Delta K_{mc}}{C''_e}$
2.1.2.	Manufacturability of the enterprise, change in the provision of the latest technologies, taking into account the available technologies in the market where the company operates (ΔK_{mc})	$D''_{1.2} = \frac{\Delta K_a}{C''_e}$
2.1.3.	Diversification of investment activities, change in the volume of external investments (participation in capital, shares of other enterprises) of a telecommunications company (ΔK_{in})	$D''_{1.3} = \frac{\Delta K_{in}}{C''_e}$
2.2.	<i>The indicators of the social subsystem</i> reflect the level of customer satisfaction with telecommunications services, the degree of impact-investment, the compliance of the wages of the company's employees with market conditions, taking into account the funds (C''_s) that were spent on external measures for social development	
2.2.1.	Satisfaction of consumers with telecommunication services is characterized by a change in the saturation of consumers of a telecommunications enterprise (ΔK_{st})	$D''_{2.1} = \frac{\Delta K_{st}}{C''_s}$
2.2.2.	The degree of impact-investment of a telecommunications enterprise has a change in the volume of social investment and charitable activities of the enterprise (ΔK_{ii})	$D''_{2.2} = \frac{\Delta K_{ii}}{C''_s}$
2.2.3.	The compliance of the wages of employees reflects the change in the level of wages of employees in relation to the average wages in the communications and informatization sphere (ΔK_p)	$D''_{2.3} = \frac{\Delta K_p}{C''_s}$
2.3.	<i>The indicators of the ecological subsystem</i> reflect the recoverability of damaged ecosystems, the environmental friendliness of the technologies used and the volume of environmental investments, taking into account the funds (C''_{ec}) that were spent on external measures for environmental development	
2.3.1.	Recoverability indicates a change in the level of restoration of damaged ecosystems by a telecommunications company in the course of its activities (ΔK_{er})	$D''_{3.1} = \frac{\Delta K_{er}}{C''_{ec}}$
2.3.2.	Environmental friendliness of the technologies used in the provision of telecommunication services, change of the telecommunications company (ΔK_{et})	$D''_{3.2} = \frac{\Delta K_{et}}{C''_{ec}}$
2.3.3.	The environmental investment of a telecommunications enterprise is characterized by a change in the volume of environmental investments (ΔK_{ei})	$D''_{3.3} = \frac{\Delta K_{ei}}{C''_{ec}}$
2.4.	<i>The indicators of the institutional subsystem</i> reflect the degree of joint activities, public-private partnerships and the image of a telecommunications enterprise, taking into account the funds (C''_{in}) that were spent on external measures for institutional development	
2.4.1.	Joint activity of a telecommunications enterprise is determined by changes in joint activities with stakeholders (ΔK_{ca})	$D''_{4.1} = \frac{\Delta K_{ca}}{C''_{in}}$
2.4.2.	The involvement of an enterprise in the process of public-private partnership reflects the change in the degree of participation of the enterprise in the implementation of government programs (ΔK_{ppp})	$D''_{4.2} = \frac{\Delta K_{ppp}}{C''_{in}}$
2.4.3.	The image of a telecommunications enterprise shows a change in the attitude of consumers to the enterprise (ΔK_m)	$D''_{4.3} = \frac{\Delta K_m}{C''_{in}}$

Source: constructed by the authors.

corrective coefficient for assessing the TE business value.

The basis for determining the effectiveness of the BD TE is based on indicators of external and internal development, which contain indicators of economic, social, environmental and institutional subsystems, as a result, they allow to determine the value of the efficiency multiplier of BD TE. The indicators of internal (Table 1) and external (Table 2) development of a telecommunications enterprise characterize the changes taking place at the enterprise of an economic, social, environmental and institutional nature, taking into account the corresponding investment in these subsystems.

The value of the balanced development efficiency multiplier, which is used as a correcting coefficient in assessing the value of a telecommunications enterprise, is calculated by the formula (1).

$$M = \sqrt[n]{\prod_{i=1}^n \left(\sum_{j=1}^m \frac{\Delta D_{ij}}{C_i} \right)^{\frac{1}{m}}}, \quad (1)$$

where M - multiplier of the i subsystem of indicators of the j type of BD indicators;

$\Delta D_{ij} = D_{ij(t)} - D_{ij(t-1)}$ – factor affecting the efficiency of a telecommunications enterprise;

C_i – costs for development activities.

Taking into account the current state of development of telecommunications companies, the authors have identified four levels of assessment of BD TE based on the use of the method of modeling real processes using scales. Since the value of the balanced development efficiency multiplier can range from 0 to 2.0, it is expedient to conditionally divide the range of values into four parts:

0.00-0.37 – unbalanced development – the assessment indicates the inharmonious development of a telecommunications enterprise with an imbalance in the economic, environmental and social subsystems that require immediate solutions;

0.38-0.67 – economically sustainable development – the assessment indicates economically harmonious development, the sufficiency of internal and external resources necessary to ensure balanced development;

0.68-0.91 – economically and socially sustainable development – the assessment indicates the sustainable development of economic and social subsystems, the sufficiency of internal and external resources necessary to ensure harmoniously balanced development;

0.92-2.00 – balanced development – the assessment indicates a harmonized, balanced development of

economic, social and environmental activities, which is characterized by economic growth, social stability and ecological balance. Enterprises with such an assessment are actively pursuing internal and external social investment, pursuing environmental and energy saving policies, and the like.

The use of such a scale helps to assess the effectiveness of the balanced development of a telecommunications enterprise not only as balanced and unbalanced, but to assess the multi-level one, allowing to assess the balance of economic, social and environmental activities of telecommunications enterprises, which can be the basis for the development of measures aimed at eliminating shortcomings in the enterprise's activities to balance the economic, social, environmental activities.

The multiplier should be applied as a ratio to the valuation of the telecommunications business (for example, using methods of capitalizing earnings, net assets (at fair value) and discounted cash flows, etc.). Taking into account the value of the balanced development efficiency multiplier, the business value of telecommunications enterprises can increase or decrease. The multiplier demonstrates the influence of harmonious balanced development on business value and emergence, that is, the formation of additional qualities in a telecommunications enterprise that are not inherent in its elements and which cannot be reduced to their simple sum. The system being created receives new qualitative characteristics that differ significantly from those that have its elements. That is, the latter serve as a prerequisite for the creation of its new qualities of a telecommunications enterprise, which also leads to globalization and informatization.

After completing the assessment of the effectiveness of the BD TE, it is necessary to identify problem areas in balanced development in order to form a triune strategy for balanced development aimed at determining the directions for further development and their implementation, predicting the future state of the TE, as well as determining an effective methodological toolkit for stimulating the BD TE, consisting of the relevant principles, tools, forms of influence, methods and means.

The process of stimulating the provision of BD TE should be based on such principles as:

1) differentiation of marketing efforts – when consuming telecommunication services, consumers have different reactions to TE offers, it causes keeping records of these differences and the orientation of service providers to specific groups of consumers is one of the conditions for the functioning of TE of the ICT market;

2) dynamic correspondence – considers maintaining a balance between the demand for services of the ICT market and the needs of the ICT market itself in dynamics;

3) consistency – considers the totality of information sources that can characterize the consumer demand of telecommunications services. The main ones include: statistical information, data from ministries, information obtained as a result of surveys; at the same time, the offer of telecommunication services of the enterprise should be formed not from the current interests of consumers and TE requests, but according to forecasts based on researches and analysis of trends;

4) overcoming social inertia – preventing the formation of stakeholders' own opinion on social responsibility under the influence of the negative opinion of the immediate environment, pleasure at least the minimum needs of all individuals in order to provide an opportunity to realize their hopes for a prosperous life;

5) continuity – TE in order to adapt the offer of telecommunications services and conduct a socially and environmentally responsible business, it is necessary to constantly dynamically develop economic, environmental and social activities, taking into account the constantly changing consumer preferences, the needs of the country's economy in ICT services;

7) environmental orientation – the formation and development of eco-culture, the approval of social and moral norms and values and the education of the environmental outlook of consumers of telecommunications services by promoting a careful attitude to the use of natural resources and adding to the solution of environmental problems through the media, public events;

5) limitedness – observance of rationality in the consumption of economic, energy, labor, technological and other resources during operation, as well as awareness of their responsibility for the consumption, production and distribution of resources;

8) complexity – the process of ensuring the BD TE should simultaneously cover the implementation of both economic, social and environmental development goals of the enterprise, take into account all possible factors and conditions that may affect the quality of development.

When stimulating the provision of BD TE, according to the authors, two forms can be used: active or passive impact on balanced development. The passive form is characterized by the fact that the free funds of the enterprise are directed to solving only production goals, covering current costs as a result of which the level of social responsibility of the TE decreases and the equilibrium is lost. The active form is distinguished by the fact that the funds of the enterprise are used not only to solve production needs, but also to meet the primary internal (personnel) and external (stakeholders) social and environmental needs.

At the same time, it is advisable to use various methods of stimulating BD TE:

- management of the creation of advisory committees, centers, etc. in the implementation of the provisions of the concept of sustainable development, coordination and specialization of individual links of the enterprise;
- control – observation, examination and experiment; comparison of the results achieved with the established norms, standards, reference values; use of advanced control methods, etc.;
- analysis – qualitative and quantitative analysis of business processes, taking into account the provisions of the concept of sustainable development and economic, social and environmental activities of the TE;
- forecasting – forecasting the level of financial stability, social and environmental responsibility based on the use of heuristic and economic-mathematical methods, taking into account environmental factors;
- monitoring – using a process approach to monitoring the effectiveness of BD TE.

The means of stimulating the balanced development of telecommunications companies can be:

1. Improvement of legislative acts on the protection of intellectual property and regulation of the ICT market to ensure the availability, opportunity and profitability of consumers of products and services of the ICT market for the social and environmental responsibility of telecommunications companies.

2. Improving the tax system by introducing simplified licensing regimes, increasing the number of available market sectors, reducing regulatory obligations, tax benefits and incentives, regressive interest rates on taxation objects of the TE.

3. Increasing the powers and functions of institutions for quality control of products and services provided in the ICT market by telecommunications enterprises. As well as increasing control by the relevant institutions on the state of social and environmental responsibility of the TE to society.

4. Provision of high-quality labor resources of TE with the help of a modern education system, health care, organization of effective social security.

The tools to stimulate the BD TE are:

1) the economic policy of TE, should take into account the requests of all consumers about the need to provide innovative telecommunication services, price differentiation for the volume and structure of services, their distribution among consumers for cities and rural areas, promotion of ICT services should intensify in the conditions of insufficient consumer awareness of new services in the ICT market (with the possession of promotion tools, it can increase the attractiveness of individual services of the providers of

these services, regulating their volume and structure, stimulating demand), material support can reduce uncertainty in the further development of TE in the ICT market by introducing new funding channels for research and development;

2) the social policy of the TE should be aimed at both the personnel and the consumer of the ICT market services, which are an important tool to stimulate demand, especially its behavior, communication style, degree of interest in interacting with consumers, etc.; on the formation of a developed social infrastructure of the TE; for sponsorship, charity for the provision of services of hospitals, orphanages, etc.;

3) the environmental policy of the TE must comply with the market requirements for the provision of competitive services and the use of equipment that are safe for others when consuming telecommunication services, can be achieved only on the basis of the development, modernization of production and increasing the level of its environmental safety; the policy should be aimed at ensuring the effective use and reproduction of natural resources, environmental protection, with full awareness of the importance and necessity of using technology and the introduction of technologies with minimal impact on the environment.

Conclusions

The presented mechanism for assessing the effectiveness of balanced development is an integral system of analytical, evaluative and resulting blocks, it allows to determine, on the basis of the multiplier, the effectiveness of the economic, social and environmental activities of a TE in the context of increasing integration trends in the world economy, the complication of multi-level relationships between the subjects of the global economic system and the emergence of new

contradictions between them. The proposed mechanism for assessing the effectiveness of the BD TE will allow tracking the dynamics of the performance of the enterprise based on the study of economic, environmental and social development subsystems, as well as making a comparison with other enterprises in the sphere on the national and world markets to achieve economic growth, social stability and ecological balance. The system of indicators has been formed that takes into account the factors of the external and internal environment, which determine the indicators of the economic, social, environmental and institutional subsystem. It is proposed to use the balanced development efficiency multiplier as a correcting coefficient when assessing the value of telecommunications enterprise business, the value of which fluctuates within the specified limits. Ranking the assessment of the level of balanced development in accordance with the scale and determine the zones of the efficiency multiplier in accordance with the developed scale, makes it possible to form a three-dimensional strategy of sustainable development. Stimulating the provision of balanced development of a telecommunications enterprise is based on the principles of differentiating marketing efforts, dynamic compliance, consistency, overcoming social inertia, continuity, environmental focus, limitation and complexity. In this case, one should use an active or passive form with the use of appropriate levers, tools, methods and means.

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RURAL DEVELOPMENT CONTEXTS - INPUT IN RURAL ATTRACTIVENESS DEFINITION

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Abstract

Rural development is associated with a variety of contexts. The attractiveness of the countryside forms a summary view of the factors that allow us to talk about the needs of the rural people to make the countryside attractive and economically viable for both locals and tourists. Within the framework of the PoliRural project, the attractiveness of rural areas is considered as a basis for the development of regional development policy. In the initial stage, the definition of rural attractiveness was based on the literature analysis and survey results. The aim of the study is to make improvements to the definition of rural attractiveness based on the contexts of rural development, regional development and rural typology. The study is based on an analysis of the literature, the needs of the pilot regions and the evaluation of selected policies. As a result, recommendations are made to policy makers. A mixed research method approach combining qualitative and quantitative techniques was used to update the initial definition of rural attractiveness. The study conceptualizes the attractiveness of rural areas as a context-based, politically determined and everyday social construct. There is no single definition of rural attractiveness in this sense due to the diversity of cultural, social, territorial, different scales and economic conditions. However, there is reason to talk about a set of factors and contexts that need to be taken into account when designing rural development policy.

Key words: rural, development, contexts, attractiveness.

Introduction

Rural attractiveness is a concept that provides a framework for promoting rural development. However, trying to define it does not turn out to be an easy task. The concept of rural attractiveness is vague. This ambiguity is determined by the social and political nature of the definition.

The initial definition is as follows: 'Rural attractiveness encompasses sustainable rural communities with access to high quality public services, a thriving and diverse local economy where agriculture related activities are complemented by sustainable tourism and other forms of employment. There is an attractive, ecologically rich and accessible countryside in which the environment and biodiversity are conserved and enhanced' (Melece, Kogut, & Shena, 2020).

The development of vision and definition of rural attractiveness is an ongoing process executed in several stages, each of which is based on the results of other PoliRural's work packages.

The original definition was based mainly on the contexts of agriculture, business and new entrants, which is largely the focus of the PoliRural project. An analysis of the different needs and policies of the regions has shown that this is not enough to cover rural diversity. The concepts influencing the attractiveness of rural areas were chosen – rural development, regional development, and typology of rural areas.

Analysing the understanding of the mentioned concepts, we come to new contexts that supplement the original definition and are essential for the understanding of the attractiveness of rural areas. Politics, different scales, economics of individual and group behaviour, leadership, public service

quality issues, symbiosis of different development approaches, cultural context, multifunctional place-based understanding, manifestations of territorial diversity in rural typologies can complement and create new accents for existing rural attractiveness. The different rural typologies point not so much to the commonalities of rural areas as to their differences. These differences should be respected in the development of common policies for different territories.

The aim of the study is not to create a new definition, but to broaden the understanding of rural attractiveness, assess the factors / contexts of rural attractiveness and provide guidance to policy makers.

The study has several parts. The first section focuses on rural development and regional development issues, and rural typologies based on a literature review. The second section evaluates rural attractiveness based on previous research in the project. In the third section, the interpretation of rural attractiveness is based on the analysis of pilot area policy. The fourth chapter summarizes the study's findings and recommendations for future changes in rural attractiveness.

Materials and Methods

The research approach envisages an extended evaluation of the literature and context evaluation in the activities of the PoliRural project in order to find additional input for broadening understanding.

A mixed research method approach combining qualitative and quantitative techniques was used to update the initial definition of rural attractiveness. Literature review was conducted using qualitative research methods: 1) the systematic review approach, using the descriptive and comparative methods

(Thomas & Harden, 2008); and 2) integrative review approach including diverse data sources, which enhance a holistic understanding of the topic of interest (Whittemore & Knafl, 2005). A common approach to the interpretation of meanings of textual data is carried out by means of content analysis (Vaismoradi, Turunen, & Bondas, 2013). Content analysis outcomes allow one to claim a certain degree of generalization of the findings, particularly in literature review and pilots analysis. Evaluation results were interpreted through statistical analysis.

Pilot statistics and analysis data are based on EUROSTAT, except for regions outside the EU. Regional classification data come from a variety of sources, including EUROSTAT, the OECD (Typology of Rural Areas). Data from other actions of the PoliRural project are used for analysis.

Results and Discussion

Based on the research approach, the literature analysis focuses on rural development concepts, revealing related contexts and areas. The literature review is structured by emphasizing several points of view (Figure 1).

Literature review

Rural attractiveness is closely related to rural development, regional development, and cultural contexts. In turn, rural development and regional development are connotations of development. The understanding of development is rooted in the cultural context and public perceptions that have changed over time, forming different theories about development. The concepts under consideration are also conditional in politics. The understanding of rural development is characterized by the diverse differences of rural areas, which are reflected in different rural typologies.

The concept of rural development has a dual nature. Nederveen Pieterse (2010) defines

development as improvement of situation and the organized intervention in collective affairs. Gradually development is becoming a multilevel, multiscale series of efforts, simultaneously taking place at different levels. The concept of development has historically been centred on the economics and as such is associated with socio-economic growth. Growth is not always the objective per se, but a means for achieving well-being, according to the social, economic, cultural and political conditions of particular populations in specific places (Pike, Rodríguez-Pose, & Tomaney, 2017).

In modernity context development theory moves towards actor-oriented, interpretative approach; thinking of plurality, polycentrism and multipolarity is getting more wide spread. In the 21st century, development is more determined by multiple modernities (Nederveen Pieterse, 2010, 2016).

Rural development is closely linked to rural understanding - rural areas and regions. Different territorial and policy approaches require different regions to be defined and distinguished. They are always linked to the purpose for which they are intended. Regional types are receiving particular attention by policy makers due to policy developments in relation to EU Cohesion Policy, the Treaty of Lisbon and the description of the European goal of territorial cohesion (EUROSTAT, 2018).

OECD rural areas are defined on the basis of the following criteria: population density and distance from major urban centres. Rural areas can be further characterized according to various additional criteria stemming from different aspects of rurality - geographical, social, economic and cultural, resulting in different geographic coverage, with important policy implications (Diakosavvas, 2006).

Following the OECD approach, several classifications of rural areas were created, including

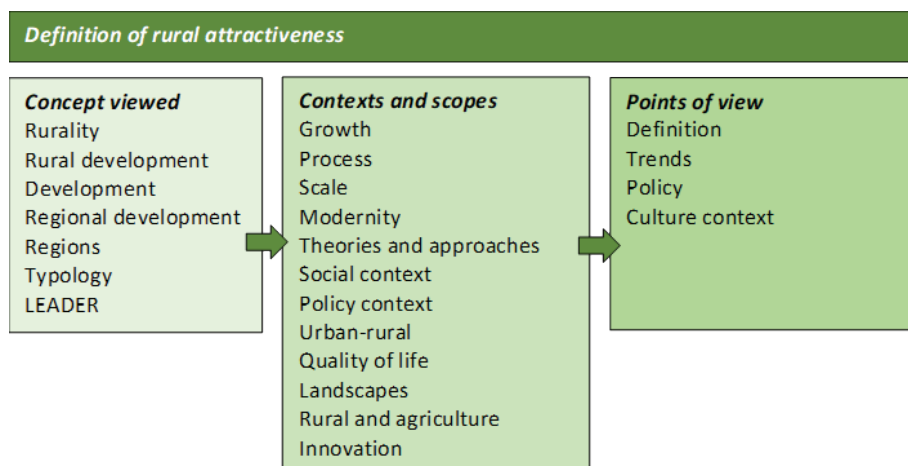


Figure 1. Concepts link with contexts.

Source: Created by author.

the normatively regulated EUROSTAT classifications. By analysing different typologies, we obtain a mosaic of territories that can be viewed as a conglomerate of diversity, depending on the criteria we select.

The concept of rural development is traditionally associated with rural-urban dualism, but in a political sense with the dualism of rural and agricultural policy. The new urban-rural relationship is far more complex than the traditional simple reciprocal exchanges between cities and villages (ESPON, 2005). The literature emphasizes mutual interdependency, interconnection making urban-rural continuum. It is often not so easy to draw the line between urban and rural, especially in suburban areas.

This is also reflected in politics. Re-territorialisation is an important dimension of what the OECD postulates as the 'New Rural Paradigm' (NRP) in Europe. According to the OECD, this paradigm includes a new, multisectoral, place-based approach to rural development that claims a need for closer links between the rural and urban economy, and to see rural development as a close interplay with regional development more generally (Horlings & Marsden, 2014; OECD, 2006). The trend is that agriculture policy has a modest impact on the future viability of rural areas. Rural development is no longer identified as a sectoral policy. A one-size-fits-all approach to rural policy does not exist. The heterogeneity of rural areas 'challenges and potentials call for tailor-made policies (Diakosavvas, 2006).

Long-term challenges – digitalization, climate change, biodiversity conservation, COVID-19 affect our needs, policy choices such as Green deal, COVID recovery package, CAP reform and changing the value system. The changes are becoming more pressing especially in recent times, when a new long-term rural development policy is being developed in the EU.

Rural development is seen not only as a specific business, but rural life can invoke a sense of community, of working together, and social change (Steiner & Atterton, 2015 p. 43).

In NRP context it is emphasized the role of local solutions in the development of potential, the development potential of each region, and the role of institutions and governance in local development. Exogenous policy action is seen as a way to trigger endogenous changes (Barca, McCann, & Rodríguez-Pose, 2012). However, neo-endogenous development can only be successful if it is people's ability to develop sustainable structures, and in doing to establish a balance that, on the one hand, facilitates all forms of innovation, creativity, new ideas and visions in acting, and, on the other hand, maintains necessary stability (Neumeier, 2011).

There are two basic approaches to regional policy: space blind versus place-based policy. The space

blind policy applies to the entire area and does not take into account local differences, while place-based focuses on the needs of a particular place. Despite the prevalence of both approaches, there is a great deal of inertia towards respect for local development (Barca, McCann, & Rodríguez-Pose, 2012).

The EU's LEADER program is an example of such an endogenous place-based policy that has developed since the 1990s. The approach has received positive reviews in promoting rural development at local level. Despite the wide territorial spread and the use of the approach not only in rural development, but also in other policy instruments, the implementation of LEADER approach is assessed ambiguously, especially due to weak performance for LEADER added values, creating innovations and bureaucracy (Courades & Brosei, 2018).

Inequalities between regions have been growing in recent decades, according to the OECD (OECD, 2018). New ways are being sought to address this issue, as past experience has not worked. The role of personal motivation in development processes, individual and collective role in development, the concept of culture in space and social environment, alternative development perspectives - all this results in new research directions – behavioral economics. Economic geography, political economy has returned to look for answers to the question of how individual and collective behaviour determines the results of regional development (Huggins & Thompson, 2016; Lee, 2017). Currently, the economy is reintegrating ethics in development conceptualization.

Rural development is associated with 'Quality of life' (QOL), which includes many material and immaterial aspects. It should be emphasized that QOL does not simply refer to income-related living standards of individuals (the economic aspect), but is a broader concept that also includes the surrounding environment, physical and mental health, education, leisure, recreation, social belonging, and so forth (Brauer & Dymitrow, 2014).

Rural development concepts are related to several contexts and areas, the most important of which are: politics, territorial scales, social and cultural contexts, quality of life. Rural development can be seen as a political and socially rooted concept at the same time. This is reflected in the definition of rural areas and rural areas at different scales, in the development of classifications, in the definition of policy approaches, and in the changing perceptions of what rural areas are and what contexts and areas they cover. QOL is such a concept that is highly socially conditioned and characterizes the attractiveness of the countryside.

Tracking change of rural attractiveness definition

The definition of rural attractiveness adopted by the PoliRural project is in a changing environment, which

Contexts	Factors of attractiveness	Wellbeing & quality of life
Growth Process Scale Modernity Theories and approaches Social context Policy context Urban-rural Quality of life Landscapes Rural and agriculture Innovation	Quality of life Territorial capital and rural assets Knowledge and innovations Ecosystem services Multifunctionality of agriculture and farm diversification Social aspects of rural areas Social innovations and innovative activities	1. Material living conditions; 2. Productive or other main activity; 3. Health; 4. Education; 5. Leisure and social interactions; 6. Economic security and personal safety; 7. Governance and basic rights; 8. Natural and living environment; 9. Overall experience of life.
Pillars of attractiveness		Categories of attractiveness
1. Availability of public and other services 2. Recreation and/or social activities 3. Living conditions, quality of life and standard of living 4. Demographic and human capital 5. Business economy and innovation 6. Social and cultural aspects 7. Environment and biodiversity		Quality of life Social capital Cultural appeal Natural capital

Figure 2. Contexts, factors of attractiveness, wellbeing and 7 pillars.

Source: Created by author based on D4.2, 2020; D1.1, 2019; D1.7, 2021.

means that its accents can be modified according to the needs of the project. The original definition was based on a number of areas that emphasized the link between rural and agricultural areas. Attractiveness factors were analysed in detail in the project (Melece, Kogut, & Shena, 2020). QOL was noted as one of the most important. It is highlighted by the Stiglitz-Sen-Fitoussi Commission (Eurostat, 2017) that the wellbeing and quality of life concepts have a framework encompassing nine dimensions. Based on the analysis, 7 pillars (D4.2, 2020) were created in the project, which served as a basis for assessing the needs of the pilot regions. Four categories were defined (D4.2, 2020).

It was acknowledged that the original definition of rural attractiveness was insufficient and had little impact on the wider rural context. The contexts of rural attractiveness analysed in this article are derived from the concept of rural development and regional development. All these contexts and different areas form the basis for a socially acceptable definition of territorially specific attractiveness.

The initial vision of rural attractiveness includes communities (social environment), sentiment (attitudes based on social and economic characteristics), quality of life – social, environmental and economic characteristics, future perspectives rooted in current trends.

Despite the different divisions, the most important is the distinction between services and infrastructure, business environment, natural and social environment (Figure 2). It is in these areas that there are territorial differences.

The project identified the needs of 12 pilot regions. The analysis of rural attractiveness factors was performed in the study based on the needs of pilots. Priority needs and their relevance to the seven pillars of attractiveness and the four categories were compared.

Category QOL in this sense is understood as the availability of services and living conditions. In the broadest sense, QOL includes all capital, assets, and all pillars. These four categories / contexts allow you to look at the pillars related to the diverse needs of pilots. Priority needs were related to pillars and categories / contexts. Of the 32 needs, the needs mentioned for the every pilot were summed up in each pillar. From these needs, the most significant ones were selected, which are the most represented in the particular pillar. The number of pilots who marked this priority need was then looked at. Finally, the needs are related to categories / context (Table 1).

From this it can be concluded that material values, access to services, and business are more important. Cultural appeal is a little overlooked. From the policy spectrum, the “old” policies related to infrastructure, services, employment, and prosperity dominate. “New” policies aimed at new challenges – climate change, transition to circular economy, bioeconomy, green economy, innovations are more characteristic of the 5th and 7th pillars.

In terms of rural attractiveness, there are inequalities between pillars and categories. In terms of new policy challenges, natural and social capital, business and new environmental technologies are becoming key drivers of rural areas.

Table 1

The most important needs, pillars and categories

Pillar	No of needs per pillar	Scarce number of priority needs of pilots	The most important priority according to the number of pilots	Number of pilots for the most important priority	Category/ context
1	7	35	Infrastructure and public transport system, connection with urban – rural areas, main cities	11	Quality of life
2	3	14	Leisure and recreation activities for diversified population	6	Cultural appeal
3	6	22	Wellbeing of all inhabitants, enhance quality of life	5	Quality of life
4	4	17	Employment for elderly people	6	Social capital
5	7	32	Transition to Circular economy, bioeconomy, green economy, innovations	8	Social capital
6	2	11	Gender equality	6	Cultural appeal
7	3	15	Adaptation to climate change, low environmental impact	8	Natural capital

Source: Created by author based on D4.4, 2020.

Pilot area missions' statements from the PoliRural project were also assessed. The goal needs to be compared to the pillars of attraction. Analysing several deliverables and different approaches to the grouping and selection of needs, the missions defined by the pilots, the overall conclusions are as follows: there is evident dominance of Pillar 5 and the weak representation of social and cultural issues (Pillars 2 and 6). These examples show how different regions value different aspects of rural attractiveness.

Pilots' policy evaluation

As part of the PoliRural project, 12 pilot regions each carried out an evaluation of a selected policy. The study sought to answer the question – what has the evaluation of policies given to the understanding of the attractiveness of rural areas? To answer the question, the evaluations of the pilot's regional policy were analysed. PoliRural is characterized by different regions. According to the NUTS classification, they cover regions from the local administrative units (LAU) to the national level (NUTS1). The same is true of the policies chosen. According to the OECD classification of regions, four types of regions are represented (Table 2).

The choice of policies was free, but was based on the basic principles developed by PoliRural, in the same way as the evaluation was based on methodological guidelines. As a result, a common regional evaluation structure could be obtained to answer this research question.

All regions had opted for policies under pillar 5 “Economic activity and innovation”, five also address needs related to pillar 7 “Environment and

biodiversity”, and only two regions were related to pillar 6 “Social and cultural aspects of rural areas”, which broadly reflects the needs of the regions analysed in the previous section. LEADER activities were selected by seven pilots, which indicates the evaluation of bottom – up and place – based policies. Other policies focused mainly on the national / regional level, which represents a top-down and space-blind approach.

The most of pilot policy evaluations was recognized as an effective, relevant and coherent policy. Despite the total pilots' positive assessment, there are a number of cases that demonstrate shortcomings of effectiveness of policy implementation, such as pre-financing difficulties, changing tax and regulatory conditions, late start program, routine work, problems with community involvement. Regions' mentioned problems related to the program coherence: organization and coordination with the various stakeholders' procedures, co-operations knowledge transfer between offices and advisors, poor coordination, delay in the implementation of projects. Relevance is mostly noted as meeting local needs, but it is mentioned that there is a lack of sustainability, there is uncertainty about the future. The analysis of weaknesses reveals the necessary improvements and accents for future action, in particular with regard to the coordination of policies between different levels and institutions, on the one hand, and the actions of policy makers, on the other; between the space – blind and top – down approaches to the nature of institutions and respect for space.

The concept of rural attractiveness and the different contexts are used in the evaluation of pilot regional

policies. Although rural attractiveness has played a role in policy evaluation, it is often not readable from pilots.

The wording of policy objectives provides insight into the contexts of rural attractiveness. In general, more emphasis is placed on economic development issues. Here are some examples of keywords: competitiveness of local companies, diversification of the rural economy, quality of life, services, well-being, employment, living conditions, tourism, agriculture, digitalization, innovation, start-up, entrepreneurs, young people, road infrastructure and investments in business, public infrastructure, new entrants, social inclusion, rural environment, ecosystems, climate changes and natural resources.

In terms of pilots, the differences are significant. For example, Flanders focuses on the landscape as a factor in rural attractiveness, Central Bohemia on 10 dimensions of rural development, Hame on young people and business, Galilee on digitization, Vidzeme on business development and rural diversification, and Ségobriga on agriculture and tourism.

These examples illustrate territorial differences and rural development needs. In addition, it forms different profiles of regions, not only resulting from formal classifications but also from policy perceptions. However, it is not possible to draw summary conclusions about the common features of the regions, their dependence on different classifications due to the small number of participants. This requires more research, which is not the task of this work.

Findings and recommendations

The study performed an update of the definition of rural attractiveness based on additional literature

analysis, tackling change of existing attractiveness development and evaluation of regional pilot policy.

The definition of rural attractiveness is influenced by public perceptions of the countryside and science-based understanding rooted in societal values and policy objectives. People make decisions about living in the countryside based on social, economic and local considerations. At the regional level, attractiveness becomes more of an economic indicator, a set of characteristics that becomes less emotional, more formalized.

Regions are focused on visions that reflect different values and views on the attractiveness of the countryside. This raises the question of whether diversity is not a basis for talking about different understandings of rural attractiveness.

The analysis of the pilot policy showed differences in the pillars of rural attractiveness. This raises the question of the different needs of the territories and the political instruments for addressing them, on the one hand, and the differences between the rural communities itself, on the other.

The attractiveness of rural areas can be seen as dual - as a socially conditional and political process that works in a complementary and mutually influential way. Existing changes in perceptions of rural development issues and new challenges determine the need for policy changes, which in turn have an impact on how rural attractiveness factors / contexts are viewed.

When developing CAP policy in the EU, or at national or regional level, agriculture should be seen in the broader context of rural development, including different funds that respect and complement territorial

Table 2

Regions by NUTS and OECD classification

Pilots	NUTS regions	NUTS policy pilots	OECD classification
Flanders	NUTS1	NUTS1	Predominantly urban
Monaghan	LAU	LAU	Predominantly remote
Cuenca	NUTS3	LAU	Predominantly remote
Vidzeme	NUTS3	NUTS3	Predominantly remote
Mazowieckie	NUTS2	LAU	Intermediate close to city
Central Bohemian Region	NUTS2	NUTS2	Intermediate close to city
Slovakia	NUTS1	NUTS1	Intermediate close to city, Predominantly rural close to city
Häme	NUTS3	LAU	Predominantly rural close to city
Central Greece	NUTS1	NUTS1	Predominantly remote
Apulia	NUTS2	NUTS2	Predominantly urban
Gevgelija-Strumica	LAU	NUTS1	not available
Galilee	does not apply	does not apply	not available

Source: Created by author based on EUROSTAT, 2018; Dijkstra & Poelman, 2011.

differences and diverse approaches to stimulating rural development. Human scale, leadership role, individual motivation influencing institutional capacity, policy coordination in rural areas, emphasis on community and social issues, sustainability of ongoing processes affecting quality of life and wellbeing are important emphases to be included in future policy actions. The attractiveness of the countryside is like an 'open chest' in which we can put what we want to keep, what is socially and politically acceptable, and take out what we want to use. We put the contexts of rural attractiveness that are in common, but we use what is important for each region.

Conclusions

1. The original definition of rural attractiveness does not need to be changed, it is broad enough.
2. The contexts of rural development and regional development are important for a common understanding of the attractiveness of rural areas.
3. The cultural context of the regions is important, influencing their values, needs and potential policies.

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4. The study conceptualizes the attractiveness of rural areas as a context-based, politically determined and everyday understanding social construct.
5. There is no common definition of rural attractiveness due to the diversity of cultural, social, territorial, different scales and economic conditions.
6. There is a reason to talk about the set of factors and contexts of rural attractiveness that must be taken into account when formulating rural development policy.

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GUERRILLA MARKETING: A CREATIVE AND SMALL BUDGET APPROACH TO ENTREPRENEURIAL MARKETING

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Abstract

This paper focuses on guerrilla marketing as an approach for creative and small budget entrepreneurial marketing communication. The aim of this paper is to answer the question how guerrilla marketing can be effectively used for entrepreneurial businesses' marketing communication. In pursuance to reach the aim, this paper employs scientific literature analysis and synthesis in the field of guerrilla marketing as well as expert interviews. Results of this research prove that guerrilla marketing is most commonly used by entrepreneurial businesses as a creative, memorable, unusual and unconventional solution of marketing communication. A very important advantage of guerrilla marketing for entrepreneurial businesses is smaller marketing budget.

Key words: guerrilla marketing, entrepreneurial marketing, creative marketing, small budget marketing, entrepreneurial business, marketing communication.

Introduction

The construct of guerrilla marketing is gaining an increasingly growing interest from the theoretical as well as practical point of view. Due to the fact that consumers daily face and have interactions with the abundance of various marketing activities, organizations aiming at building awareness and gaining competitive distinctiveness are forced to look for new ways to communicate with their consumers and influence the behaviour of their prospect and existing consumers in the desired way. Nowadays, in the field of marketing and marketing communications, more and more attention is being given to innovative and creative ideas of marketing and marketing communication.

In contemporary business environment we notice a growing number of newly established entrepreneurial businesses. Marketing communication is particularly important for entrepreneurial businesses to successfully enter the market, grow business and stay competitive. With marketing communication, entrepreneurial businesses strive to attract, inform and persuade prospective and existing consumers.

However, changing consumer needs and habits, intensifying competition and the growing flow of marketing communication, stipulate entrepreneurial businesses to look for new, creative, and low-budget marketing communication solutions to grab consumers' attention and influence their buying behaviour. Entrepreneurs face the need for marketing communication not only to convey a message about the presence of their business, brand, product or service, but also to build the brand image and long-term relationships with consumers through memorable experiences.

Moreover, for entrepreneurial businesses it is extremely important to communicate with their consumers with as small budget as possible. Due to this, entrepreneurial businesses realize that traditional

marketing 'weapons' are not enough effective and cost-effective in helping an entrepreneurial business to build brand awareness, image, competitive advantage, and encourage consumer buying behaviour in a desired way. In addition, traditional marketing and traditional marketing communication tactics can be easily copied by competitors.

For all the above-mentioned reasons, entrepreneurial businesses face the need to change traditional marketing communications to more creative and engaging consumers, without spending too much of a budget. Creativity, combined with the elements of traditional marketing, leads to the abundance of new forms of marketing communication. In addition, opportunities to execute creative marketing communication with a small budget leads to the growing popularity of unconventional marketing communication solutions between entrepreneurial businesses.

Problem of the research. Since entrepreneurial businesses in Lithuania, other EU countries and even worldwide live in the world of growing popularity of guerrilla marketing, guerrilla marketing as a creative and small budget marketing communication tool is still an underexplored topic in the scientific literature. Scholars argue that this field needs deeper knowledge and tools on how to use guerrilla marketing for creative and small budget entrepreneurial marketing. Because of this scarcity in the theory, the question is not if entrepreneurial businesses should use guerrilla marketing but how it should be used for their marketing communication to be creative and to ensure small budget. The absence of comprehensive theoretical and practical information on how guerrilla marketing could be used for creative and small budget marketing communication raises many issues for the owners and marketing people at entrepreneurial businesses.

Object and aim of the research. The object of the research is the use of guerrilla marketing for marketing

communication of entrepreneurial businesses. The aim of the research is to ascertain how guerrilla marketing could be used for marketing communication of entrepreneurial businesses.

Objectives of the research. Objectives of this research are set in the following logic: (1) to analyse theoretically definitions of guerrilla marketing; (2) to analyse opportunities of guerrilla marketing provided for entrepreneurial businesses; (3) to analyse theoretically types of guerrilla marketing; (4) to conduct expert interviews in order to identify how guerrilla marketing is used in practice by entrepreneurial businesses.

Materials and Methods

The paper is organized using theoretical and empirical research approach. Research for this paper was conducted in Lithuania from 2020 to 2021. The research was conducted over a period of 3 months, starting from December, 2020, which addressed guerrilla marketing terminology, provided opportunities of guerrilla marketing for entrepreneurial businesses, types of guerrilla marketing and application of guerrilla marketing in practice by Lithuanian entrepreneurial businesses.

Theoretical analysis. Pursuing to reach the aim of the paper, theoretical research methods that are used in this paper embrace scientific literature logical analysis, synthesis and interpretation. The author of this paper used analysis and synthesis of scientific literature to execute research and assess existing concepts of guerrilla marketing and entrepreneurial marketing, and to determine guerrilla marketing trends in the 21st century.

Theoretical analysis is organized by doing scientific guerrilla marketing theory analysis and guerrilla

marketing trends examination. The author used international scientific publications that are indexed in Scopus, Web of Science and other international databases. For the theoretical analysis keyword search in Business Source Complete (EBSCO), Emerald Management eJournals Collection, SAGE Journals Online, ScienceDirect, Taylor & Francis and Web of Science databases was done to collect international scientific publications for this research. Keyword search focused on the keyword of ‘guerrilla marketing’ during the years of 1984–2021. Another related keyword of ‘entrepreneurial marketing’ was included in the scientific articles search to make a comparison of the popularity of the two related keywords in the contemporary marketing literature (as usually guerrilla marketing is a most widely used marketing communication method in the entrepreneurial marketing).

The review of scientific publications was started from the year 1984 purposively. As many researchers point out (e.g. Ahmed *et al.*, 2020; Ay, Aytakin, & Nardali, 2010; Bigat, 2012; Diaa, 2017; Hutter & Hoffmann, 2011; Onurlubaş, 2017; Pakson & Chang, 2010; Powrani & Kennedy, 2018), guerrilla marketing concept was first developed by Jay Conrad Levinson in 1984 in the book ‘Easy and Inexpensive Strategies for Making Big Profits for your Small Business’. Since guerrilla marketing is still a relatively underresearched topic in the literature of marketing, it has been decided to start a review of publications from its first mentioning. Analysis of the availability of scientific articles in the selected databases during the period of 1984–2021 showed that guerrilla marketing is not a popular topic for publications, compared to other related topics of marketing (e.g. entrepreneurial marketing). Results of the analysis on availability

Table 1
Scientific articles with ‘guerrilla marketing’ and ‘entrepreneurial marketing’ keywords published during 1984–2021

Database	Quantity of scientific articles with keyword ‘guerrilla marketing’				Quantity of scientific articles with keyword ‘entrepreneurial marketing’			
	1984-1990	1991-2000	2001-2010	2011-2021	1984-1990	1991-2000	2001-2010	2011-2021
Business Source Complete (EBSCO)	9	4	187	92	0	2	8	3
Emerald Management eJournals Collection	0	2	5	7	10	57	228	789
SAGE Journals Online	2	1	3	5	0	1	13	48
ScienceDirect	0	0	3	7	18	47	56	214
Taylor & Francis	0	1	0	4	1	3	16	70
Web of Science	0	15	23	64	4	370	1235	5945
TOTAL:	11	23	221	179	33	480	1556	7069

of scientific articles in the selected databases with keywords 'guerrilla marketing' and 'entrepreneurial marketing' during the period of 1984–2021 is detailed in Table 1.

Expert interviews. After the presentation of results from theoretical analysis, findings from empirical research method are outlined. For the empirical research semi-structured expert interviews were conducted with 2 experts of guerrilla marketing from Lithuania to identify how guerrilla marketing is used in practice by Lithuanian entrepreneurial businesses.

Online interview method using Microsoft Teams was used to collect primary data from 2 Lithuanian experts of guerrilla marketing. An initial plan to do live expert interviews became impossible due to the quarantine period in Lithuania caused by the COVID-19 pandemic.

A single questionnaire was prepared for conducting interviews. Two guerrilla marketing experts that represented two different marketing communication agencies were invited to share their opinion about the trends of guerrilla marketing and current situation of Lithuanian entrepreneurial businesses related to the use of guerrilla marketing.

The interviews were carried out by doing online meetings and discussions. Interviewees were provided with guidance when answering questions and asked for clarification or elaboration when it was necessary. Expert interviews questionnaire was constructed of 13 open questions. At the beginning of interviews, the aim of the interview, its logic and expectative results were highlighted. Expert interviews were carried out in February, 2021. Duration of both interviews was approximately 20–40 minutes.

Results and Discussion

Many researchers from marketing field agree that the concept of guerrilla marketing is usually used as an umbrella name for various non-traditional marketing practices and has become widely used in practice for unconventional marketing communication.

In 1990s, guerrilla marketing has reached its popularity. More and more organizations started to adopt guerrilla marketing theory in their marketing campaigns (Khare, 2017). But as Hutter & Hoffmann (2011) point out, although guerrilla marketing is applied more and more often in the practice of marketing, there is lack of accompanying research. Jay Levinson, often referred as the father of guerrilla marketing, since 1984 has written more than 30 books about guerrilla marketing (Khare, 2017), but guerrilla marketing is still one of these new methods (Yildiz, 2017).

Guerrilla marketing by using exceptional promotion methods, nowadays has become an important competitive tool for companies (Yildiz,

2017) because the stiff competition in today's era has necessitated the use of modern and out-of-the-box marketing practices (Gupta & Singh, 2017). Guerrilla marketing is most suitable for organizations which do not have resources to confront directly with their large competitors and have to deploy unexpected and creative tactics to reach their target customers (Dinh & Mai, 2015).

Theoretical conceptualizations on guerrilla marketing

Companies attempt to reach private worlds of consumers and give them memorable experiences with their brands by using guerrilla marketing tools (Ay, Aytekin, & Nardali, 2010). Guerrilla marketing originated from guerrilla warfare operations where the armed group utilized unconventional techniques in fighting the enemy, even to the point that violates the ordinary rules of engagement (Ahmad *et al.*, 2014). Thus, guerrilla marketing is fundamentally guided by the guerrilla warfare and the steps taken (Onurlubaş, 2017). The term of guerrilla marketing is an example of the transfer of military-related and warfare-related terminology to the marketing domain (Baltes & Leibing, 2007).

Guerrilla marketing can be as different from traditional marketing as guerrilla warfare is from traditional warfare (Khare, 2017). Guerrilla marketing differs from traditional marketing in that it is creative and allows for maximum turnover while spending the least amount of money since it is able to benefit from innovative strategies and promotional tactics (Babu, 2018). The imperative part of guerrilla marketing is the surprise that differentiates it from traditional marketing in which ads are showcased at unusual places in a strange setting that captivates consumers' attention (Ahmed *et al.*, 2020).

Guerrilla marketing is a flourishing marketing approach (Diaa, 2017) and a modern technique in product marketing that makes the use of unconventional or unusual means of promoting the product to the market (Ahmad *et al.*, 2014; Babu, 2018). Guerrilla marketing is non-conventional and inexpensive kind of marketing strategy in which high energy and imagination are dominant (Ahmed *et al.*, 2020; Babu, 2018). However, Levinson (1984), Diaa (2017), Khare (2017), Pakson & Chang (2010) add time element stating that guerrilla marketing is an unconventional marketing method based on time, energy and imagination instead of big marketing budgets.

Guerrilla marketing includes the search for fresh and original ways of luring new buyers, retaining the old ones, and influencing buyers to spread the word to others (Ahmad *et al.*, 2014). Thus, guerrilla marketing is understood as funny, humorous and unexpected advertising campaigns that can be easily memorized (Diaa, 2017).

According to Hatch (2005, p. 53), guerrilla marketing is defined as ‘any activity that uses means other than traditional media to communicate a brand’s name and position to prospects’. Accordingly, guerrilla marketing is described as being fancy, atypical, unusual, original, provoking, flexible, dynamic, innovative and creative (Hutter & Hoffmann, 2011).

Guerrilla marketing is not only the definition. Guerrilla marketing is a way of thinking. It is a mentality too (Khare, 2017). To be able to successfully apply guerrilla marketing, companies need guerrillas (salespersons) that would invest all their time and energy to the marketing activities of the company (Ay, Aytakin, & Nardali, 2010).

Guerrilla marketing is more about matching marketers’ creativity than matching marketing budgets (Khare, 2017). These strategies are characterized by creativity and ingenuity, and they are designed to minimize the use of financial resources (Gutierrez, Diaz, & Gutierrez-Salcedo, 2019). The main goal of guerrilla campaigns is to increase customer awareness and interest about the product and brand (Navratilova & Milichovsky, 2015). Guerrilla marketing activities tend to be eye-catching and surprising when used, thus, being highly efficient in terms of gaining customer attention (Baltes & Leibing, 2007). Guerrilla marketing is based on a marketing philosophy in which creative methods that competitors cannot imitate are used and the customer can be influenced by interesting tactics. Guerrilla marketing is often associated with insidious marketing or sneaky tactics that are used without revealing them to people (Onurlubaş, 2017).

The low-cost effect is a fundamental characteristic of guerrilla marketing (Gutierrez, Diaz, & Gutierrez-Salcedo, 2019). Guerrilla marketing is a low-cost strategy which makes it ideal for businesses that do not have massive marketing budgets (Babu, 2018), because it can be applied with a little budget in the company (Iqbal & Lohdi, 2015). Thus, guerrilla marketing is a marketing method that enables low-budget brands to place their products in consumer consciousness by creating sensations that emerge in unexpected places and times with creative, extraordinary, exciting and surprising tactics (Onurlubaş, 2017).

Provided opportunities for entrepreneurial businesses by guerrilla marketing

Small and medium-size companies use guerrilla marketing strategies due to the low budget and because they cannot afford the traditional way of marketing channels (Ahmed *et al.*, 2020). Since the beginning, guerrilla marketing always brings inspiration to the marketers and especially small businesses, because it requires imagination instead of money to promote the products and services. Compared to the giant corporations, small business owners do not have enough money to waste in the ineffective marketing

campaigns. They want to use limited budgets to the right targets (Khare, 2017). Nowadays, when classical marketing methods have lost their update and consumer behaviours have changed, guerrilla marketing is considered as an ideal marketing method for entrepreneurs with a small budget and big dreams (Onurlubaş, 2017).

Guerrilla marketing is specifically geared for small businesses (Diaa, 2017; Dinh & Mai, 2015; Khare, 2017) and entrepreneurs to help them gain publicity from minimal sources (Diaa, 2017). Guerrilla relies on psychology rather than experience, judgment, and guesswork (Diaa, 2017). The benefits of guerrilla actions are first and foremost an increase in consumers’ attention (Hutter & Hoffmann, 2011; McNaughton, 2008). While implementing guerrilla marketing tactics, a small size is actually an advantage instead of a disadvantage (Pakson & Chang, 2010).

Innovative implementations by guerrilla marketers provide important advantages to the businesses (Ay, Aytakin & Nardali, 2010). Businesses using this strategy can obtain the desired position in the mind of the customers compared to their competitors (Onurlubaş, 2017). Guerrilla campaigns have great effects on brand image, brand attitude, purchase intention (Babu, 2018; Iqbal & Lohdi, 2015), purchase decision (Ahmed *et al.*, 2020) and increased customer loyalty (Ay, Aytakin, & Nardali, 2010).

Guerrilla marketing campaigns are more creative than the traditional marketing campaigns and perceived as more amazing, comical and interest raising (Babu, 2018; Iqbal & Lohdi, 2015). Because guerrilla marketing uses interesting and striking methods, they may be noticed by consumers more (Yildiz, 2017). Guerrilla communication is intensely focused on generating publicity (McNaughton, 2008). Guerrilla marketing emerges as a perfect opportunity to take a proactive approach in breaking clusters and conveying the message (Gokerik *et al.*, 2018). Guerrilla marketing campaigns drive sales, increase mindshare, and function as public relations (McNaughton, 2008).

The company that employs guerrilla marketing strategy is able to increase its ads’ effectiveness, gain new customers and increase its profits (Ay, Aytakin, & Nardali, 2010). Seven guerrilla marketing effects are: novelty, aesthetics, relevance, clarity, humour, emotion arousal, surprise (Ahmed *et al.*, 2020; Dinh & Mai, 2015; Powrani & Kennedy, 2018). Guerrilla marketing should be bold, creative, unexpected, engaging, flexible, low cost, targeted and simple (Khare, 2017). This means of communication, however, can also be risky, particularly when the message of the campaign is misunderstood by consumers (Gokerik *et al.*, 2018).

Types of guerrilla marketing

Guerrilla marketing itself has become an umbrella term for more specific communication strategies

designed to engage and surprise consumers with their products and services (Ristevska-Jovanovska, 2017). Guerrilla marketing has a broad range and variety of advertising tactics (Diaa, 2017) and enumerative list of instruments (Hutter & Hoffmann, 2011). Guerrilla marketing consists of a chain of strategies that can be applied with a little budget in the company (Iqbal & Lohdi, 2015), which is very appealing for entrepreneurial businesses.

Different researchers distinguish a variety of different types of guerrilla marketing. Ahmed *et al.* (2020) believe that guerrilla marketing techniques consist of viral marketing, strange occurrences, street graphics, and memorable events that have a positive and significant influence on the purchase decision. Yildiz (2017) argues that guerrilla marketers aiming to create marketing methods that are dynamic, creative and can adapt to change the use of street graphics, strange events, product placements and memorable events. Khare (2017) lists examples of guerrilla marketing approaches including ambush marketing, buzz marketing, viral marketing, grassroots and also events. Hutter & Hoffmann (2011) distinguish ambient, sensation, viral, buzz marketing and astroturfing as guerrilla marketing instruments. Ristevska-Jovanovska (2017) provides the largest number of different guerrilla marketing types, including ambient, ambush, stealth, viral, street marketing and astroturfing.

Ahmad *et al.* (2014) point out that with the use of social media in conducting guerrilla marketing, Facebook, Twitter and MySpace have started a phenomenon known as buzz marketing. Gutierrez, Diaz & Gutierrez-Salcedo (2019) add that the internet, especially social networks, have increased the ways to interact with consumers through methods such as viral marketing, buzz marketing, stealth marketing, ambush marketing and public relations.

Stealth marketing is believed to be the most popular technique in guerrilla marketing (Ahmad *et al.*, 2014). There is a number of techniques that are used in stealth marketing in which one technique, celebrity marketing is most often used in practice by the market leaders (Shakeel & Khan, 2011).

Scientific literature also provides ideas on more specific methods that entrepreneurial businesses could apply for guerrilla marketing campaigns. Khare (2017) suggests making use of: product giveaways, free demonstrations and consultations, intrigue-generating mystery to engage customers, peer marketing, SMS text and video messaging, Roach Baiting and buzz marketing using actors, live commercials using people to do live commercials and bill stickers. Babu (2018) suggests relying on smaller, more localized brick and mortar strategies like: graffiti, stencil graffiti, reverse graffiti, stickers,

undercover marketing (also known as stealth marketing), flash mobs, publicity stunts, treasure hunts, urban environment, online guerrilla marketing campaigns in the form of viral videos, user generated content competitions and creative landing pages.

Different types of guerrilla marketing may demonstrate different effects. A research made by Hutter & Hoffmann (2011) proved that each guerrilla marketing type consists of three effects: surprise, diffusion and low cost. However, a research of Hutter & Hoffmann (2011) also proves that some types are primarily applied to maximize the surprise effect, some types are explicitly designed to stipulate a diffusion effect and some instruments mainly aim at cutting advertising costs. For example, viral marketing, buzz marketing and guerrilla PR are instruments that explicitly try to stimulate the diffusion effect (Hutter & Hoffmann, 2011).

Following the strategies, types and instruments of guerrilla marketing distinguished by various researchers in the scientific literature and based on the personal teaching experience, the author of the paper distinguished the most commonly used categories and types of guerrilla marketing together with a short type overview that is presented in Table 3.

Expert interviews on the usage of guerrilla marketing in practice of entrepreneurial businesses

Expert interviews provided insights about the usage of guerrilla marketing in practice of Lithuanian entrepreneurial businesses. When asked which companies usually use guerrilla marketing, experts pointed out that guerrilla marketing, as part of marketing strategy, is usually chosen by innovative businesses that are not afraid to take risks. This shows that in Lithuania, guerrilla marketing is most often used by entrepreneurial businesses aiming at standing out of the market and attracting the attention of consumers.

Experts believe that the main goals of entrepreneurial businesses when using guerrilla marketing usually are: to increase sales; to build awareness when launching a new business or introducing a new brand, product or service; to present a new business, brand, product or service to potential and existing consumers in a non-traditional way. Later, when a business, brand, product, or service becomes better known, the goal becomes to maintain consumer loyalty, create image, or remind the market about the offering. Also, experts pointed out the goal of reaching a wide audience with a small budget is usually the main goal of guerrilla marketing campaigns.

When experts were asked what guerrilla marketing types are most often used by entrepreneurial businesses in Lithuania, it was indicated that entrepreneurial businesses most often use non-traditional stands, because it ensures live contact with the consumers,

Table 2

Categories and types of guerrilla marketing

Category of guerrilla marketing	Type of guerrilla marketing	Type overview
Outdoor guerrilla marketing: when something removable or temporary is added to existing urban environment	Projection advertising	Projection advertising is executed when digital billboard or building is used to project an advertisement. This type allows promoting brand in unexpected areas and reach large audiences.
	Street marketing	Street marketing is any kind of an unconventional outdoor promotion in public areas. The goal is to use non-traditional methods and advertising spaces to earn a greater amount of attention.
	Wild posting	Wild posting is when static posters are placed in dense, urban areas to attract maximum attention. It is inexpensive and reaches high degree of exposure with the help of posters, stickers and other means in intensive areas. Sometimes it is done without permission.
	Ambient guerrilla marketing	Ambient guerrilla marketing may be both outdoor and indoor. It is when advertising is placed on unusual things or in unusual locations. This helps to increase brand awareness creatively.
Indoor guerrilla marketing: like outdoor guerrilla marketing but done indoor		
Event ambush guerrilla marketing: executed when audience of an in-progress event is used to promote brand in a noticeable way and often without permission	Ambush guerrilla marketing	Ambush guerrilla marketing is executed when marketing campaigns are organized at events that the product/ service is not directly affiliated with, but it looks like it is. When using this type marketers of brands uses the audience of an event to promote their product/ service.
Experiential guerrilla marketing: requires the audience to interact with brand	Experiential marketing	Experiential marketing is executed when experiences between brands and consumers are created and activation to bring brands to life and interact directly with audiences is used. It is usually done by creating immersive, pop-up experiences that encourages people to talk about the brand.
	Grassroots marketing	Grassroots marketing fosters spreading the word about product or service while focusing on creating personal and distinct connections between consumers and brands. Here, niche group of supporters is reached to spread the word about brand's awesomeness among themselves and other likeminded people.
	Buzz marketing/ viral marketing	Buzz marketing/ viral marketing creates word-of-mouth about a particular campaign or product/ service through conversations or discussions on social media.
	Astroturfing	Astroturfing is the term for campaigns or messages that appear to be naturally occurring but authentic buzz about product/ service is created via reviews or endorsements, while hiding financial and business links between the originating company and the message, making message more acceptable by the public.
	Stealth marketing	Stealth marketing is when product/ service is advertised to people but they do not know that.

Source: created by the author.

affects positive emotions of consumers and exclusivity is achieved.

According to experts, Lithuanian consumers respond incomparably better and accept guerrilla marketing campaigns better than those of traditional marketing. Usually, consumers tend to not 'run away' from guerrilla marketing promotions and voluntarily participate in them. Also, consumers are more interested in non-traditional solutions because they evoke pleasant, positive emotions and even surprise, which naturally increases their interest.

According to experts, consumers are usually more likely to search for a brand in stores, 'google' it and visit websites of companies due to guerrilla marketing campaigns. Entrepreneurial businesses also enjoy word-of-mouth and viral effects as consumers tend to share unexpected and 'different' advertising. Non-standard guerrilla marketing solutions encourage consumers to share their experiences and emotions with others not only verbally but also in social media. Thus, thanks to guerrilla marketing, entrepreneurial businesses organically achieve word-of-mouth

effect to their promotional activities. According to experts, guerrilla marketing encourages consumer engagement, distraction, interest, information sharing, and the purchase of the promoted products or services.

While it is evident that guerrilla marketing brings many benefits to entrepreneurial businesses, experts were asked to share their experience on whether it is really worth organizing guerrilla marketing campaigns in terms of costs. Experts have reassured that, in general, guerrilla marketing campaigns are worth organizing because of the high level of consumer interest which leads to lower costs per contact. This is mostly noticeable when agency is not hired to run the campaign and the entrepreneurial businesses come up with their own ideas and implement the campaign with their own resources. Experts supported scientific literature analysis results that guerrilla marketing requires lower budget compared to the traditional advertising.

Experts concluded that in recent years guerrilla marketing has become a very popular form of marketing communication among entrepreneurs in Lithuania, and more and more entrepreneurs are incorporating it into their marketing communication. Thus, guerrilla marketing in Lithuania is currently becoming a very popular form of marketing communication among Lithuanian entrepreneurial businesses, and it is very likely that these businesses will increasingly surprise consumers with unique guerrilla marketing solutions in the future.

Conclusions

Analysis of scientific literature allows to conclude that utilization of guerrilla marketing in entrepreneurial

businesses' marketing communication is becoming increasingly apparent. There is a growing consensus among entrepreneurs that guerrilla marketing is not only a creative marketing communication tool that provides good results when influencing consumer behaviour, but also a marketing communication tool that requires a smaller budget which is often a problem for entrepreneurial businesses. It also brings great effect on brand awareness, brand attitude, brand image, purchase intentions, purchase decisions, increased customer loyalty, etc.

Results from expert interviews confirmed that guerrilla marketing is most commonly used by entrepreneurial businesses as a creative, memorable, unusual and unconventional solution of marketing communication. Experts pointed out a very important advantage of guerrilla marketing for entrepreneurial businesses – smaller marketing budget. Entrepreneurial businesses using guerrilla marketing usually aim at increasing sales, brand awareness and customer loyalty, and building positive, exclusive image. Consumers of entrepreneurial businesses usually find guerrilla marketing as a more attractive form of advertising than traditional advertising. As a result, entrepreneurial businesses can easily achieve their marketing communication goals if they are able to impress consumers. According to experts, it is crucial for the success of a guerrilla marketing campaign that it evokes positive emotions and encourages engagement of consumers. According to experts, guerrilla marketing has a direct impact on consumer behaviour: it encourages consumer involvement, interest, information sharing and encourages buying.

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EVALUATION OF SOCIAL ENTERPRISE STATUS CRITERIA IN LATVIA

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Abstract

Social entrepreneurship plays an increasing role in national and sectoral strategic policy documents, education, research and the business sector. The number of social enterprises in Latvia tends to increase; at the same time, however, a large number of enterprises were not granted social enterprise status, or the applicants refused the status. Therefore, the aim of the research is to analyse criteria for granting social enterprise status in Latvia. The research found that defining and measuring social impacts were the main challenges faced by social entrepreneurs in obtaining social enterprise status. The issue of non-distribution of profits is discussable because potential social entrepreneurs are not sufficiently motivated to apply for social enterprise status as well as face problems with the attraction of investors. Besides, the criterion of involvement of target groups in the executive or supervisory body of a social enterprise as well as the employment of employees is often formally met. Overall, it could be concluded that the entrepreneurs who have previous experience in administrative work or entrepreneurship do not face significant problems in meeting the criteria for granting social enterprise status when applying for the social enterprise status and filling in the relevant documents. However, most often the individuals who do not have previous experience in administrative work or entrepreneurship do not find it easy to meet the criteria and apply for the status.

Key words: social enterprise, social entrepreneurship, social enterprise status.

Introduction

In recent years, social entrepreneurship has become a focus in public policies, research, education and the business sector. Various kinds of social enterprises are established in the world, and in Latvia as well. Besides, there is a belief that social enterprises are the future of the economy; however, there are relatively few social entrepreneurs in Latvia. This could be explained by the fact that this field began to develop faster owing to purposeful activities only after 2015 when the Social Entrepreneurship Association of Latvia was established, which carried out educational and informative campaigns, while in 2018 the Social Enterprise Law entered into force. Besides, the fact that social entrepreneurship has now become a horizontal field and is used as an instrument in various areas to achieve certain goals represents some progress in this field. For example, social entrepreneurship is incorporated in the Resocialization Policy Guidelines for 2022–2027 to facilitate the integration of prisoners and probation clients into society and the labour market. Social entrepreneurship is also referred to in the informative report Circular Economy Strategy for Latvia stating that the reuse of goods as a business pattern creates opportunities for a new kind of social entrepreneurship. In addition, the educational standard SCHOOL 2030 stipulates that social entrepreneurship must be included in the curricula.

It is a positive fact that in recent years an increasing number of researchers in Latvia have focused on social entrepreneurship issues. It can be explained by the fact that today technological progress is reshaping global economic development and changing the overall welfare of societies (Grinberga-Zalīte & Hernik, 2019). In their research, scientists and young researchers analyse the nature of social enterprises

and focus on the definitions of the concept (Stupeņa, 2015; Dehtjare & Riashchenko, 2015; Kalve, 2012), the historical aspects of social enterprises and the role of social enterprises in the social economy (Dobeļe, 2014; Bikse, Rivza, & Riemere, 2020; Licite, Perkune & Auzina, 2020), international experience in social entrepreneurship (Freimanis, 2012), measurements of the social impacts of social enterprises (Kumačeva, 2018; Gintere, 2020), relevant legal frameworks (Groma & Licite, 2019) and support instruments for social enterprises (Veigure & Zorina, 2017; Aps, Ūlande, & Lipponen, 2018; Lis *et al.*, 2017). Overall, research on social entrepreneurship plays a key role in promoting the social entrepreneurship and educating the public on it. One of the last most important and comprehensive research studies on this field was the one commissioned by the European Commission; the research study identified the ecosystem in social entrepreneurship in the Member States of the European Union, incl. in Latvia (Līcīte, 2018). However, the scientific research done in Latvia has not performed in-depth examinations of the criteria for granting social enterprise status, which significantly affect the development of this field.

The criteria for granting social enterprise status are defined in the Social Enterprise Law that entered into force on 1 April 2018. The law defined not only the criteria for granting social enterprise status but also laid down the procedure for government support for this kind of entrepreneurship, as well as required that social enterprise statistics need to be started to be collected, and for this purpose the Register of Social Enterprises was established. Since the entry into force of the law, 155 enterprises have obtained the social enterprise status (140 of them are active social enterprises), while 50 enterprises were not granted the

status or the applicants refused the status (Ministry of Welfare Register of Social Enterprises, data as at 31 December 2020). This caused discussions on the reasons why the enterprises refused social enterprise status. A research study (Bogane, 2020) found that meeting the social enterprise criteria was one of the factors. Therefore, the aim of the research is to analyse the criteria for granting social enterprise status in Latvia. To achieve the aim, the following specific research tasks have been set: 1) to describe the process of granting social enterprise status; 2) to analyse the criteria for granting the social enterprise status.

Materials and Methods

To identify challenges in relation to social enterprise criteria in Latvia, 13 interviews with social entrepreneurs were conducted in Latvia. To gain a comprehensive and in-depth understanding of the research problem, 13 social entrepreneurs were interviewed; the interviewees were selected according to the following criteria:

- economic activity in various areas: environmental protection, culture and art, education, retail, knitwear production, building an inclusive civil society, etc.;
- economic activity in various regions of Latvia;
- work integration social enterprises working with different target groups;
- production of goods and services;
- duration of the social enterprise – for analysis, both new social enterprises that have started their operation relatively recently (less than 3 years) as well as those that have been operating for about 20 years were selected.

In addition, the interviews were conducted with representatives of the Ministry of Welfare and the Social Entrepreneurship Association of Latvia (SEAL).

The research analysed papers from international journals on social entrepreneurship, data on social enterprises collected by the Ministry of Welfare, as well as the legal framework of the Republic of Latvia governing the field of social entrepreneurship in Latvia.

Results and Discussion

The process of granting social enterprise status. The Ministry of Welfare (MoW) is responsible for the promotion and development of social entrepreneurship in Latvia. It grants social enterprise status to an enterprise based on a decision by a specially established Social Enterprise Commission (consisting of 10 members). The Social Enterprise Commission is governed by several legal documents, with Cabinet Regulation No. 101 Regulations regarding the Social Enterprise Commission being the most important one. The commission consists of representatives of five ministries, as well as five candidates who have been nominated by associations and foundations on an open competitive basis. According to a representative of the SEAL, an assessment and decision by the commission is important – a social entrepreneur receives a multidisciplinary qualitative view of his/her enterprise, as well as each application for social enterprise status is assessed in essence and meaning. However, several social entrepreneurs indicated in the interviews that the commission used to ask them questions mostly about the social impacts, yet the

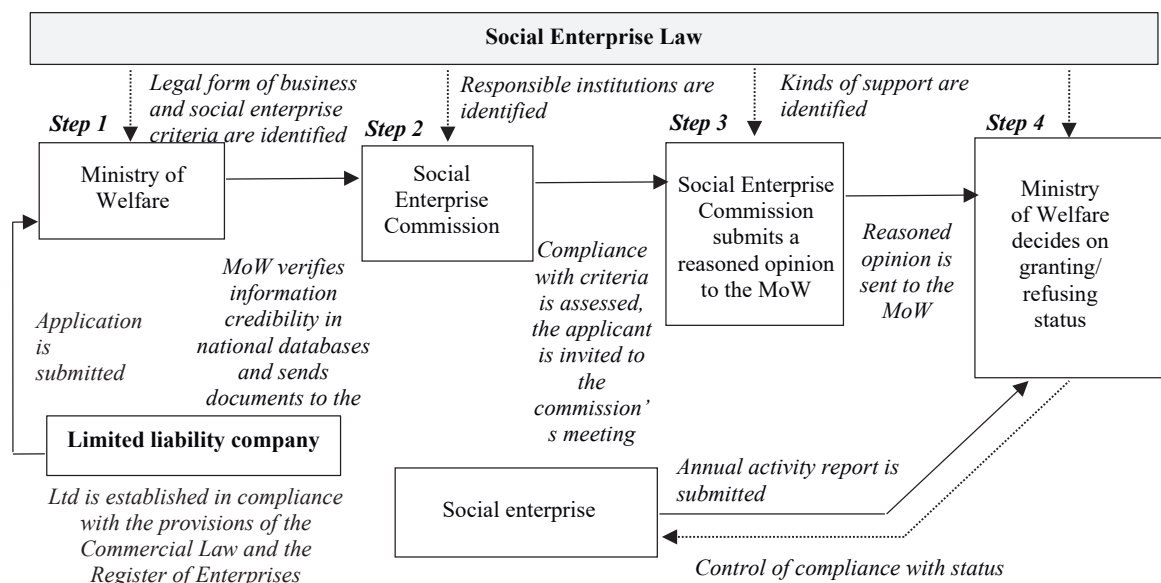


Figure 1. Scheme of granting social enterprise status in Latvia.

Source: authors' construction, 2020.

entrepreneurs would also appreciate the fact that the commission had a person from the entrepreneurial environment who would also assess the enterprise's economic viability. The process of granting social enterprise status is shown in Figure 1.

As shown in Figure 1, initially a Ltd is established (in compliance with the provisions of the Commercial Law and the Register of Enterprises), which submits a completed application form to the Ministry of Welfare that verifies the information in databases and assesses whether the potential candidate for social enterprise status meets the criteria and invites the applicant to a meeting of the commission. As a result, the Social Enterprise Commission sends a reasoned opinion to the Ministry of Welfare, which makes a decision on granting or refusing the status. The status is granted within one month from the submission of the application and relevant documents. After the social enterprise status has been granted, basic information on the enterprise is included in the public Register of Social Enterprises, which is available on the website of the Ministry of Welfare.

It is a positive fact that the enterprises that were granted social enterprise status are annually monitored, i.e. before 1 May each year, any social enterprise must submit to the Ministry of Welfare an activity report confirming that the requirements set for the social enterprise have been met and the tasks set in the statute to achieve the goal have been performed. The activity reports submitted facilitate the supervision of social enterprises (the reports contribute to meeting the requirements by the social enterprises, provide information on their social impacts, as well as their tasks performed and to be performed in the future) and contribute to the exchange of information on social enterprise activities, problems, suggestions as well as self-control and planning.

It should be noted, however, that previous research studies (Bogane, 2020) have established that the procedural part – obtaining social enterprise status – was not perceived positively by social enterprise representatives, which is mainly due to the fact that the process of obtaining the status was rather long and bureaucratic. The social entrepreneurs involved in the interviews conducted by the authors also pointed out this fact. In the interviews, the social entrepreneurs also noted that they were not sure whether they would be able to meet the criteria, especially with regard to measuring their social impacts. It could be concluded that, overall, the process of granting social enterprise status is well-developed, governed and understandable; however, there are some challenges in meeting the criteria, which are analysed in detail in the research.

Areas of economic activity and the legal form of a social enterprise. According to the Social Enterprise

Law, social enterprise status could be obtained by a limited liability company (Ltd) that implements creative economic activities with a positive social impact, e.g. it provides social services, forms an inclusive civil society, contributes to education, supports science, works on environmental protection, animal protection or cultural diversity. It could be concluded that the Social Enterprise Law, on the one hand, provides for a variety of economic activities to be carried out by social enterprises (with only a few exceptions to the kinds of activity defined in Section 9 of the Social Enterprise Law). It should be noted that the areas of economic activity mentioned in the law are only some examples, not a complete list, which means that social enterprises are not significantly limited in choosing the most appropriate kind of economic activity. The main thing is that social enterprises pursue social goals, which are divided into three categories by the law, giving each category specific performance indicators:

- employment of groups at risk of social exclusion – at least 50% of the employees are representatives of the target groups specified by the Ministry of Welfare (Cabinet Regulation No. 173 Regulations regarding Groups of Population at Risk of Social Exclusion and Procedures for Granting, Registering and Monitoring Social Enterprise Status);
- improvements in the quality of life of groups at risk of social exclusion by providing services to the representatives of these groups – not less than 30% of the total services provided are supplied to the target groups;
- other social goals – at least 50% of the self-defined social impact targets have been achieved.

As regards the first two categories of social enterprises, most of the entrepreneurs interviewed understood everything in relation to meeting the mentioned social goal criteria, whereas the social entrepreneurs that chose the 'other' category were often confused. This is partly due to the prevailing perception among the public that a social enterprise is only concerned with the employment of groups at risk of social exclusion or the provision of services to target groups; as a result, potential social entrepreneurs do not understand that they could apply for social enterprise status if their social goals are achieved in a different aspect. In addition, the research has found that the entrepreneurs who did not have previous experience and knowledge of social entrepreneurship as well as the definition and measurement of social goals faced more administrative challenges. The representative of the SEAL also pointed out that often social entrepreneurs lacked an understanding of social impacts, and the government had not defined generally

accepted principles for measuring the impacts. Besides, an analysis of the information collected by the Ministry of Welfare on the most common reasons for refusing social enterprise status reveals that entrepreneurs have most often inaccurately indicated the goal, the social problem was not clear or the planned activity made an insufficient social impact. This indicates that defining and measuring a social goal is one of the largest challenges faced by social entrepreneurs in Latvia.

In Latvia, the legal form of social enterprises, which may only be a limited liability company, should be indicated as a relative restriction in the criteria for identifying social enterprises. Although there was a lot of discussion on the most appropriate legal form for a social enterprise (Brencis & Šīna, 2016) before the entry into force of the Social Enterprise Law, which suggested granting the status of social business operator instead of social enterprise status irrespective of whether the organization is a Ltd, an NGO, a municipal institution or an agency. However, given the fact that the operation of any social enterprise is based on economic activity, associations and foundations were not included in the law as potential beneficiaries of social enterprise status because, according to the Law on Associations and Foundations, they were allowed to perform economic activity only in the form of auxiliary activities.

On the one hand, the fact that in Latvia the issue of a specific legal form for a social enterprise is governed by law is positive; however, as acknowledged in previous research studies (Bogane, 2020), such a restriction has narrowed the definition of a social enterprise and 'left overboard' the entities that also operated in public and national interests, thereby helping to tackle various social problems. Besides, although the introduction of the law was aimed at defining the boundaries and content of social entrepreneurship, it has insignificantly contributed to the identity of social entrepreneurs and social enterprises. The representatives of the Ministry of Welfare pointed out that they had no plans to change or supplement the list of legal form entities that could apply for social enterprise status in the coming years.

Irrespective of the subjective view of the scope of social enterprises, an enterprise needs the legal form of a limited liability company – either it is an existing limited liability company that adapts its activities to the requirements set by the law, or a new limited liability company is established, which complies with the requirements set by the law – in order to officially join the community of social entrepreneurs. It should be noted that associations may establish limited liability companies that may apply for social enterprise status and become the owner of a social enterprise. It could be concluded that the Social Enterprise Law does

not oblige existing associations and foundations to establish a new limited liability company and/or to stop their economic activity. It is up to each organization to decide which way to choose and how to continue their activity. As the representatives of the Ministry of Welfare pointed out in the interviews, in the future it might be necessary to consider some incentives and a transition period for associations that could qualify for social enterprise status in order to make the procedure of application for it more understandable and easier.

Social enterprise criteria. To obtain social enterprise status, not only the criteria for the legal form of a limited liability company but also other criteria must be met (Section 5 of the Social Enterprise Law):

- the statute of the Ltd defines the company's social goal as the only and main goal of the company's activity;
- a meeting of Ltd participants has made a decision on obtaining social enterprise status;
- the Ltd does not distribute the profit, but invests to achieve the goals set in the statute;
- the Ltd employs at least one employee;
- the Ltd implements a democratic (participatory) management style: a representative of the target group is included in the executive or supervisory body or an advisory body for the Ltd is established, which includes a representative of the target group or a representative of the association or foundation representing the interests of the target group, or an expert in the relevant field.

Development of a statute. Previous research studies suggest that creating or adapting relevant statutes is not an easy job (Bogane, 2020). The research conducted by the authors also reveals various situations regarding adapting a statute and meeting the requirements for other documents. For some social entrepreneurs, it was not difficult, whereas others hired a lawyer or a consultant to help to do the paperwork (especially in situations where a Ltd is re-established and has no previous experience in drafting a statute). Some other entrepreneurs indicated that they used the support provided by the Social Entrepreneurship Association of Latvia to understand the overall situation regarding documentation and the nature of social entrepreneurship.

Paid employees. In Latvia, social enterprises are mostly micro or small enterprises with a small number of employees (Licite, 2018). This is mainly due to the limited experience of social enterprises and their recent emergence in the country, yet overall meeting this criterion did not cause significant problems for social enterprises, as the definition of the criterion in the legal framework is clear and understandable. However, at the same time, testing this criterion was a challenge for the Ministry of Welfare because in

practice dishonest situations were identified, i.e. a social entrepreneur employed an employee and paid a salary of 0 EUR, as a result of which the criterion was formally met, yet the practical implementation did not make any sense.

Reinvestment of profits in the enterprise. One of the biggest subjects of discussion on the criteria among social entrepreneurs is the non-distribution of profits or reinvestment in the enterprise. On the one hand, Santos' theory (Santos, 2012) could be emphasized. According to the theory, the main goal of a social enterprise is to gain social influence as opposed to making a profit, which is the main goal in business, thereby defining the main difference between the two business models. However, other theorists criticize Santos' theory (Agafonow, 2014) because profit is needed to create social impacts. A similar situation has been found in previous research studies analysing this problem in Latvia (Bogane, 2020). Santos' theory is more often agreed with by those social entrepreneurs in Latvia whose companies had social enterprise status for a relatively shorter period or it was their first experience in business. This could be explained by the fact that most social enterprises in Latvia are young and do not make a profit in the first years of their operation; therefore, meeting this criterion is not perceived as a significant obstacle. The kind of economic activity in which social entrepreneurs are engaged often generates no high profits, and it is mentioned as an argument for non-distribution of profits; therefore, the reinvestment of profit is considered an acceptable criterion.

At the same time, it should be emphasized that there was a discussion among social entrepreneurs on the future of this criterion. On the one hand, it was emphasized that the withdrawal of a certain share of profits in the form of dividends could encourage more individuals to engage in social entrepreneurship, as well as contribute to entrepreneurship, as profit reinvestment is typical of the nongovernmental sector. In addition, it might make it more difficult to attract potential investors in the future. However, on the other hand, the social entrepreneurs interviewed also admitted that it was difficult for them to make a profit in Latvia, and many of the entrepreneurs had been working without profit for several years. Accordingly, changing this criterion (allowing a certain proportion of profits to be withdrawn in the form of dividends) would not significantly change their activity. The representative of the SEAL also pointed out that international experience has proved that profits should be reinvested in the company; however, she indicated that the distribution of some profits could be allowed in the future, or a specific period of operation (age) or the development stage of the enterprise could be stipulated for the distribution of profits.

Involvement of target groups in the enterprise's executive or supervisory body. The social entrepreneurs involved in the research indicated that the involvement of the target groups was in place, yet it was mostly formal, i.e. the representatives of the target group were informed about the enterprise's plans and activities. The formal involvement of target groups was mainly due to the fact that the entrepreneurs assume financial obligations, as well as responsibility for the enterprise's economic activity; therefore, the target groups were often informed about decisions rather than directly involved in decision-making. Overall, it was also noted that the role of executive/supervisory bodies was not clearly defined in the Social Enterprise Law. The entrepreneurs agreed that it was a good idea to encourage social entrepreneurs to take into account the interests of the target group, yet they did not see the point in imposing an obligation to create an appropriate institution. Several entrepreneurs emphasized that they had formally met the criterion by involving friends, acquaintances or family members in the relevant institution, who theoretically performed the relevant functions. At the same time, the social entrepreneurs involved in the research also gave some positive examples of target group involvement, e.g. renovating rooms and setting up a café, inviting a disabled person (in a wheelchair) to see whether the place is suitable for people with reduced mobility, thereby improving and changing the environment to be adapted for people with reduced mobility. The entrepreneurs also often consulted with target group representatives on implementing better activities for the target groups.

It could be concluded that, overall, the criteria stipulated in the Social Enterprise Law do not significantly restrict social entrepreneurs, yet the experience in meeting the criteria was different. For those who had previous experience in administrative work, this was not a problem, while some of them hired a specialist, a consultant, or used the support of the Social Entrepreneurship Association of Latvia to meet the criteria. In addition, meeting the criteria was also influenced by the size of the enterprise (including available human resources and their competencies and level of knowledge).

Conclusions

1. The criteria for granting social enterprise status are stipulated in the Social Enterprise Law. For those entrepreneurs who have previous experience in administrative work or business, meeting the criteria does not cause significant problems when applying for social enterprise status and filling in the relevant documents. However, most often those who do not have such previous experience have some difficulties in meeting the criteria and making an application.

2. The process of granting social enterprise status is regulated by law and easily to be understood. The challenges relate to relatively complex and lengthy administrative processes for obtaining social enterprise, which could discourage the applicants from applying for the status.
3. One of the largest challenges for social enterprises is to identify and describe the social goal of their activity. The authors recommend that the Ministry of Welfare develops guidelines for measuring social impacts, as well as gives some examples of how social enterprises engaged in different fields measure their social impacts, thereby facilitating the measurement of social impacts by potential social entrepreneurs.
4. With regard to the reinvestment of profits, the authors propose allowing some part of the profits to be distributed in the form of dividends in the future, thereby providing some incentive for entrepreneurs to apply for social enterprise status as well as attract investors in the future.
5. Taking into account unfair situations where a social enterprise concludes an employment contract with an employee and pays a salary of 0 EUR, thereby only formally meeting the criterion of employees, the authors recommend supplementing the list of social enterprise criteria with the following criterion: 'a social enterprise applies the principle of social justice to its employees, thereby ensuring fair pay', as well as setting a minimum workload or minimum working hours for the employees of target groups employed in a work integration social enterprise.
6. The involvement of target groups in the executive or supervisory body of a social enterprise is an essential criterion for social enterprises, which ensures democratic governance. However, the authors suggest that the owner or manager of the enterprise could be in place of the representatives of the target groups if s/he has previous experience in working with the specific target group.

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THEORETICAL ASPECTS OF SOCIAL ENTREPRENEURSHIP IN THE CONTEXT OF ENVIRONMENTALISM

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Abstract

As the fight against climate change grows, the world is increasingly focusing on developing social entrepreneurship to address environmental challenges. By creating not only legislation and support programmes, Latvia is also involved in the development of social entrepreneurship, following the priorities of social entrepreneurship set out in the Europe 2030 and Latvia 2030 strategies.

The research aim is to examine the theoretical role of preserving and protecting the environment by means of social entrepreneurship. To achieve the aim, specific research tasks were set: 1) to review the relevant scientific literature and make a comparison of different definitions of social entrepreneurship; 2) to define the factors affecting environmental help and to examine how social entrepreneurship takes part in improving these factors; 3) to identify which European Union Member States most actively use social entrepreneurship in solving environmental problems.

The research showed, given that social entrepreneurship is a relatively new concept, its long-term concept is unclear, and the ambiguous definition hinders the development of common sets of measures. Given that the criteria for setting up a European social enterprise vary, most EU Member States focus on engaging target groups in social entrepreneurship, while only 8 EU Member States view environmental protection as an essential component of social entrepreneurship.

Key words: social entrepreneurship, social enterprise, environment, sustainable development.

Introduction

Social entrepreneurship developed rapidly in the early 2000s and has attracted a lot of researcher attention; since this field of science continues to expand, the identification and development of social entrepreneurship is hindered by obstacles such as legislative gaps, ambiguous definitions and a systematic lack of theoretical facts about the factors affecting social entrepreneurship that make the sector fragmented (Sassmannshausen & Volkman, 2013; Mackle *et al.*, 2018). **Social entrepreneurship involves identifying, assessing and using business opportunities in a way that creates social value for meeting the basic and long-term needs of society** (Austin, Stevenson & Wei-Skillern, 2006). Social value pertains to meeting the short-term and long-term necessities of society such as nutritional food, clean water, housing, education and medical services to the members of community who do not have access to them, but it does not make any profits (Cetro & Miller, 2008). The emphasis on social value is the basis for a number of definitions of social entrepreneurship (Peredo & McLean, 2006; Shaw & Carter, 2007). For example, Austin, Stevenson, Wei-Skillern (2006) have defined social entrepreneurship as a “contemporary, beneficial activity that could be promoted by both non-profit organizations and private or public sector entrepreneurs”. The definition places a strong emphasis on two components. First, the definition highlights the creation and importance of innovation, which coincides with the Schumpeterian view of entrepreneurship, which means that social entrepreneurs could be viewed as promoters and creators of social innovation (Casson, 2005). Second,

the definition emphasizes the different actors in social entrepreneurship, which means that this form of entrepreneurship is adaptable not only to for-profit or non-profit organizations but also to public authorities (Cetro & Miller, 2008). Social entrepreneurship differs from the theory of entrepreneurship, yet there are a number of similarities. French economist Jean-Baptiste Say has defined an entrepreneur as an individual who implements an intention and changes an outlook in such a way that it changes the reaction of the idea on society (Martin & Osberg, 2009). However, the dissimilarity between entrepreneurship and social entrepreneurship originates from the purpose of creation. The main goal of social entrepreneurs is to solve a social problem and not to make a profit, as is the case with classical entrepreneurship.

Materials and Methods

The present research employed several methods to achieve the research aim and accomplish the tasks. The monographic and descriptive methods were used to theoretically discuss various definitions of social entrepreneurship, as well as to interpret the research results based on scientific finding. Analysis and synthesis were used to survey the elements of the problems and to identify regularities. Induction was employed to make scientific assumptions based on individual elements or facts and identify causal relationships.

Results and Discussion

Single definition of social entrepreneurship has not been implemented, yet it is an integral part of the European market economy, with various business

Table 1

Comparison of the definitions of social entrepreneurship

Definition	Author	Emphasis on	What is different from other definitions
Social entrepreneurship means producing goods or services with the aim of solving a social problem or benefiting society, rather than maximizing profits for business owners. The types, formats, goods, services of social entrepreneurship could be very different, social enterprises could be large, small, international or local, yet they are all united by the desire to create high social value added by using business methods.	Social Entrepreneurship Association of Latvia	The emphasis is placed on tackling a social problem or creating a benefit for society.	The definition specifies no forms, types, no specific, understandable boundaries.
The main goal of social entrepreneurship is to make a social impact and not to generate a profit for the owners. It operates under market conditions, in a business-like and innovative way, thereby producing goods and services. For a social enterprise, its social mission is more important than profit. Profit is not a goal, but a means. It is reinvested in achieving the social goal, not redistributed. The way work is arranged or the system of ownership reflects the principles of social justice, democracy and participation. Its origins are linked to civil society.	Ministry of Welfare of the Republic of Latvia	The emphasis is placed on the fact that the aim is not to make a financial gain.	The definition refers only to the fact that profit is not a goal, no conditions or forms of entrepreneurship are specified as well as who can engage in social entrepreneurship.
The main purpose of social entrepreneurship is to tackle social or environmental problems. A social entrepreneur supplies goods or services by reinvesting the profit earned by the company or allocating it to the achievable social goal. Social entrepreneurship is not uniform: it can employ individuals of different genders, interests, social groups and opinions, the main common feature is that social entrepreneurs pursue a social mission or goal.	School for Social Entrepreneurs	The emphasis is placed on the fact that profit could be reinvested or allocated to an achievable social goal.	It mentions that social entrepreneurship is not uniform and that people should have a common feature to engage in social entrepreneurship.
Social entrepreneurship is a kind of entrepreneurship that offers original solutions to society's biggest social problems. Social entrepreneurs are aspiring and tenacious in proposing new ideas for overall positive change. Social entrepreneurs offer consumer-friendly, recognizable and ethically acceptable ideas that reach a target audience, thereby making the idea widely available and implementable.	Bill Drayton	The emphasis is placed on the fact that social entrepreneurship offers innovative solutions.	It differs from other definitions in that it lists the characteristics and traits of the entrepreneur.

Source: authors' own compilation based on Social Entrepreneurship [w.y.]; What is social..., [w.y.]; Support for social..., [w.y.]; What is a..., 2015; Drayton, 2015.

principles, forms and goals. Social entrepreneurship is based on creating social changes by offering various innovative solutions (Social Entrepreneurship, [w.y.]). A comparison of the definitions of social entrepreneurship is shown in Table 1.

Examining the evolution of social entrepreneurship in the context of environmentalism allows us to conclude that social entrepreneurship emerged as early as the beginning of the 20th century when the Royal Society for Nature Conservation was founded in Great Britain (Vickers, 2010). In the second half of the 20th century, however, measures emerged to prevent pollution from large companies (Lowe & Goyder, 1983; Jamison *et al.*, 1990). In the 1970s and 1980s, activists sought to develop a rational, sustainable political principles in which economic democracy was

a decisive factor. Worker cooperatives were a popular institutional form whereby a new resource efficient economy could be built although little notice was paid to other forms of social economy (Vickers, 2010).

The development of social entrepreneurship has been facilitated by various scientists, politicians and entrepreneurs (Table 2), who have made a significant contribution to its visibility and created businesses that form the basis of social entrepreneurship in the 21st century.

The scientific literature emphasizes the long-term results of social entrepreneurship. However, since social entrepreneurship is a rather new concept, its long-term concept is unclear. James B. Taylor is one of the founders of social entrepreneurship who emphasized that social innovation includes the ability

Table 2

Founders of social entrepreneurship

Name, surname	Year	Contribution to social entrepreneurship
James B. Taylor	1970	One of the founders of social entrepreneurship who emphasized the importance of innovation and highlighted social problems.
Charles Leadbeater	2000	The report entitled “The Rise of the Social Entrepreneur Social” drew the attention of scientists to social entrepreneurship research.
Michael Young	1950-1990	The School of Social Entrepreneurship (SSE) was set up to help young entrepreneurs to set up social enterprises.
Andrew Mawson	2007	Contributed to urban regeneration in London.
Fritz Schumacher	1973	The author of the book “Small is Beautiful” drew the attention of social entrepreneurs to environmental aspects.

Source: authors’ own compilation based on Abeysekera, 2019.

of activists and social entrepreneurs to see social needs and come up with new solutions to tackling social problems (Abeysekera, 2019).

People are constantly interacting with the environment, and it affects their life quality, healthy life years and health disorders. With regard to health, the World Health Organization (WHO) defines the environment as “all the physical, chemical and biological factors external to a person that impact behaviour”. Environmental health includes prevention of control of illness, trauma, and disability related to the interplays between individuals and their habitat (Worldwide health risks..., 2017).

The Agency for Disease Prevention and Health has identified 6 factors, each highlighting the environmental health element:

- Outside air condition.
- Quality of water.
- Toxic substances and hazardous waste.
- Accommodations and communes.
- Infrastructure and monitoring.
- Ecological health in the world.

Maintaining a healthy ecosystem is essential for the quality of life and healthy life years. Preventable global environmental factors account for 23% of total deaths and 26% of deaths of children under the age of 5 (Worldwide health risks..., 2017).

Since profit is viewed as the main motivator of entrepreneurship, the scientific literature examines different concepts of entrepreneurship that include various motivations examined in a broader social, political and environmental context (Downing, 2005; O’Neil, 2009; Drakopoulou Dodd & Anderson, 2007; Nicholls, 2008). The scientific literature specifically focuses on entrepreneurship motivated by eco-friendly values, also called green entrepreneurship or eco-environment (Isaak, 2002; Schaper, 2002; Tilley & Young, 2009; Dixon & Clifford, 2005) or sustainable entrepreneurship (Dean & Mc Mullan,

2007). Dean and Mc Mullan use the ecological and health economies to show that ecological collapse and degradation results from lack of success in market which reflect the potential for profitability as market-based solutions could be enlarged by entrepreneurs in cooperation with governments (Dean & McMullan, 2007).

Other authors focus on building a better understanding of the diverse goals and merits of young people engaged in green activities. This means eco-entrepreneurship is closely linked to corporate social responsibility and ethics on entrepreneurship, as well as the values and beliefs of entrepreneurs and business owners, and managers in relation to production and consumption in a more environmentally friendly way (Masurel, 2007). Sustainability-oriented entrepreneurship could play two roles: filling gaps and creating catalysts (Parrish & Foxon, 2009; Chell, 2007; Walley & Taylor, 2002). The first concerns filling gaps in the supply of critical communal and ecological goods and solutions that are not produced by commercial sectors and government structures. Sustainable entrepreneurs could also be particularly motivated through creating a friendly business environment to transform the industries in which they are engaged and who want to make profit while also contributing to solving ecological problems and preserve nature resources (Parrish & Foxon, 2009; Austin *et al.*, 2006).

Tilley and Young (2009) base their opinions on a critique of the general picture of entrepreneurship and its role in ecological modernization theory to give an alternative model. They agree with other authors and argue that in a world of constrained resources, political involvement is insufficient to promote environmental and social sustainability. Sustainable businesses need to go beyond the inclusion of additional criteria for ecological and social efficiency, adequacy and environmental equity (Dyllick & Hockert, 2002).

Tilley and Young's definition of wellbeing states that sustainable entrepreneurs provide benefits to the economy, society and the natural environment. This alternative model of sustainable entrepreneurship helps individuals to respect the values and measures taken to build a sustainable social business: "This is a challenge that is very difficult in practice, as many elements are theoretical at best. However, entrepreneurs have the qualities needed to experiment, take risks and implement these elements of the model and move towards sustainable entrepreneurship development. Entrepreneurs should therefore be viewed not only as investors in a successful economy but also as the driver of a sustainable society" (Tilley & Young, 2009).

Even though social entrepreneurs are often identified as goal orientated people with a daring and direct mission who set up social businesses, there has been a moderate change in the social entrepreneurship literature from focusing on individuals to understanding social entrepreneurship as a process that results in innovation (Perrini & Vurro, 2006; Diochon & Anderson, 2009).

In Europe, the criteria for setting up a social enterprise differ significantly, as do the development stages and plans for social entrepreneurship. The European Commission's website publishes reports on social entrepreneurship in 27 European Member States (Social enterprises and..., 2020). Comparing the reports, the authors used keywords to analyse which Member States focused on environmental protection and nature conservation and which reports focused mainly on the social inclusion of target groups or other factors.

The Member States that referred to environmental protection and nature conservation as one of the main goals of social entrepreneurship were:

- Bulgaria; its Social Enterprise Law states that one kind of social entrepreneurship involves the implementation of measures to ensure nature protection, biodiversity and ecological balance. The Bulgarian Centre for Not-For-Profit Law holds an annual competition for the best business plans to support future social entrepreneurs, including those wishing to work in the field of environmental protection and conservation (Social enterprises and..., 2020);
- social enterprises in Austria could be divided in several categories, e.g. the non-profit organization sector, in which 39 (4.7%) out of 837 enterprises were engaged in nature protection and conservation, while in the ECO-WISE sector, which had 194 enterprises, 35 (18%) organizations dealt with nature protection. The Austrian report states that education and science, followed by nature conservation, are key priorities for the younger

generation of entrepreneurs setting up or wanting to start social enterprises (Social enterprises and..., 2020);

- The Albanian report states that the Social Enterprise Law specifies no common definition and criteria, yet the law states that social enterprises are those that deal not only with the involvement of target groups but also with nature protection and conservation. However, one of the criteria for setting up a social enterprise is the employment of at least 30% of the target groups in the enterprise; therefore, solving environmental problems cannot be the primary goal (Social enterprises and..., 2020);
- The Greek report focuses on women's employment rates, while in relation to environmental protection and nature conservation it states that this sector accounts for 6% of the total social enterprises in Greece (Social enterprises and..., 2020);
- In Croatia, a social entrepreneurship development strategy was developed and adopted in 2015; the strategy defines social entrepreneurship as "a kind of entrepreneurship that is based on social, environmental sustainability and economic principles, and the profit is reinvested in the enterprise." The environmental factor is also incorporated in nine criteria for setting up a social enterprise (Social enterprises and..., 2020);
- There is no legislation on social entrepreneurship in Cyprus, yet various initiatives, which state that protecting and preserving the environment is one of the courses of action for social entrepreneurship, have been developed. However, in Cyprus the main focus is placed on the employment of target groups, stipulating that at least 40% of the employees of the social enterprise have to represent the target group. The Cyprus report also mentions support instruments for social enterprises, one of which, the Agricultural Development Plan, specifically focuses on environmental issues, ensuring biodiversity as well as protecting and preserving nature (Social enterprises and..., 2020);
- The Danish Social Business Act states that one of the goals of social entrepreneurship is to protect and preserve the environment. Denmark is one of the countries where nature conservation is one of the priorities of social entrepreneurship, thereby the progress in this field has been very fast over five recent years. In 2013 in Denmark, according to the report, of the total social enterprises, 6% were engaged in nature conservation, while in 2018 the figure was already 29%. This indicates that the Danish

government constantly follows global trends in environmental protection and supports the entrepreneurs who want to preserve natural values and combat climate change (Social enterprises and..., 2020);

- The Czech Republic is the only European country where the main emphasis is put on the development of environmental social entrepreneurship. Although the Czech legislation also sets criteria for the employment of target groups, there are various programmes and funds for environmental protection, as well as specific criteria for the development of social entrepreneurship linked to environmental protection. This conception identifies specific areas represented by environmental social entrepreneurs, support programmes, as well as refers to case studies and certain tax relief (Social enterprises and..., 2020).

It should be emphasized that social entrepreneurship, which is linked to environmental factors, is still at the stage of initial development in Europe. Of the 27 Member States that have submitted their social entrepreneurship reports, only two, Denmark and the Czech Republic, have taken serious measures regarding environmental factors.

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Conclusions

1. Social entrepreneurship began emerging in the 20th century. Michael Yunus and James B. Taylor could be considered to be the main founders of it, yet there is still no single definition of or criteria for social entrepreneurship.
2. Social entrepreneurship plays an important role in protecting the environment and conserving nature, as it highlights each of the six elements of environmental health identified by the Agency for Disease Prevention and Health.
3. The development stages of and plans for social entrepreneurship vary in the European Union; therefore, in most EU Member States the emphasis is put on the involvement of target groups in social entrepreneurship. However, eight EU Member States – Bulgaria, Austria, Albania, Greece, Croatia, Cyprus, Denmark and the Czech Republic – have integrated the environmental dimension into their development conceptions.
4. Only two EU Member States – Denmark and the Czech Republic – have set environmental factors a priority in their national social entrepreneurship development plans.

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TOURISM TAX MODEL FOR DEVELOPMENT OF REGIONS

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Abstract

Tourism enables export, creates work places and additional income for regional development. In 2020, due to Covid-19 virus the global tourism industry shrank by 72% increasing unemployment, bankrupting small companies, which was most evident in regions. The Organisation for Economic Co-operation and Development (OECD) has mentioned the need for establishing the competitive advantage of Latvia in surrounding regions as one of the challenges of the Tourism Policy of Latvia. In order to succeed, there is a need for additional funding, which can be acquired through tourism tax which is a well worldwide known method, also in Latvia, with more than 100 years of history. Globally, there are different models of tourism tax. However, there is no clear indication towards the applicability of a single tourism tax model for development of regions which would be applicable to the case of Latvia. This research reveals that despite the identified problems, introduction of tourism tax is a well based decision which is rationalised through positive impact on the number of tourists. The deployed AHP method defined the model Fixed rate model for enterprise as the most appropriate option for the given situation.

Key words: regional development, analytic hierarchy process, tourism tax model.

Introduction

Tourism is one of the most important sectors of economy in the world. The tourism industry has positive impact on countries globally in following domains: (1) generated additional income (for development of infrastructure, regional development, e.g.) (Agaraj & Murati, 2009); (2) increased exports; and (3) creation of new workplaces (WTTC, 2019). The annual research on the economic impact of Travel & Tourism by the World Travel & Tourism Council (WTTC) indicates that in 2019 the tourism sector accounted for 10.3% of global GDP (WTTC, 2019) and for 330 million workplaces or 9.9% of the total employment (Grimaldi, 2019).

According to the data by World Tourism Organisation (UNWTO), there were almost 900 million (72%) less international tourists in travel destinations during the period from January to October 2020 compared to the corresponding period in 2019. This means that the overall decrease of tourism exports can be estimated at 772 billion euros. Reduction of international travel creates losses in terms of income at the amount of 1.07 trillion euros. Due to Covid-19, estimated 100 – 120 million direct jobs have been lost in small and medium business sector, which are located in the regions (UNWTO World Tourism Barometer, 2020). Meanwhile, tourism is also associated with negative impacts: (1) degradation of local, natural environment due to rapid development of tourism activities (Pazienza, 2011); (2) air pollution due to air transport (IATA, 2018); (3) pollution created by tourism (Valleab, Pintassilgoab, Matiasab & Andréc, 2012). In order to reduce the impact of tourism on the environment, to develop appropriate infrastructure, manage the pollution and waste management, as well as to promote tourism development, every state, region, local-government are in a need for financial resources. One of the

solutions to acquire them is through introduction of tourism tax. The UNWTO has defined 45 different taxes that are collected from tourists. Over 30 of such taxes are collected directly from tourists themselves and 15 from tourism companies (Batic, Predrag, & Devčić, 2012). The opposition for the implementation of tourism tax has been associated with the following negative aspects: (1) implementation of tourism tax can negatively impact the tourist flow; (2) non-optimised tourism tax system can impact functionality of the system. **Research problem:** the unclear implementation approach of tourism tax model for the regional development. **Research aim:** defining of the most appropriate tourism tax for regional development. **Research tasks:** (1) analyse scientific and literature sources; (2) compile information on the tourism tax worldwide; (3) refine and develop the methodology; (4) evaluate the appropriate tourism tax model for regional development; (5) collect information and provide conclusions.

Materials and Methods

Research place: Riga planning region in Latvia.
Research period: January 2018 till December 2020.
The theoretical part of research is based on scientific articles and literature, documents defining tourism development and key principles of tourism tax system. In order to evaluate the benefits arising from introducing tax system, the good practice and changes in number of tourists in regions with such system were assessed. The necessary statistical data on number of tourists abroad and in Latvia were acquired through publications of the World Bank, statistical outlooks, databases and annual overviews by the Central Bureau of Statistics of Latvia (CSB). Further analysis was aimed at selected 12 regions from countries covering all tourism regions (UNWTO, 2016) in which the tourism tax has been introduced. There are

considerably more regions selected for the study from Europe, since there is higher number of countries with introduced tourism tax system in this region. Also, it is evident by the statistics that Europe is attracting considerably more foreign tourists compared to other regions (Roser, 2018).

The practical part of the research is based on series of interviews. The first cycle of interviews took place from 30.04.2019. to 01.11.2019 with the aim of defining the problems related to implementation of tourism tax system and included six interviews with tourism industry experts. The professional activities of experts were directly related to the tourism tax or its introduction as well as interviews with members of the local municipality.

The second series of interviews took place over the period 01.11.2019. – 14.05.2020. while pursuing an analysis on the most appropriate model for introduction of the tourism tax system for region development based on the Riga planning region case with the use of Analytic Hierarchy Process (AHP) method. The expert choice was based on the premise that participants have to represent the tourism industry, hospitality sector which are in most contact with the introduction of tourism tax, as well as there was a need to include members of association and representatives of public and local institutions (also the RTAB) that are responsible for introduction of the tax system.

Research limitations: (1) the diversity of titles of tourism tax create obstacles for proper collection of information; (2) the limited access to the information from archives and databases from other countries to carry out proper historical analysis of introduction of the tax. (3) time and quality limitations of the sources of tourism development in Latvia, also limited by the language barrier in the form of historical written text in old Latvian orthography based on German phonetic principles; (4) limited access to undisclosed internal public governance data on the collected amount of funds collected as tourism tax. The Latvian tourism tax up to this moment has been a topic of research that has been investigated thoroughly while a negative attitude towards the tax system by the society and industry members has been observed (Geide, 2019). This has manifested also in the response rate by the invited expert interview and survey participants: of 11 invited experts only 5 responded and agreed participating in AHP sessions.

The AHP is a multi-criteria decision making method including quantitative and qualitative analysis, which was chosen, because it is well suited for complex multi-decision making in complicated problem situations (Frolova, 2007). Of the three types of AHP: (1) calculation of criteria weights; (2) calculation of point option matrix; (3) option ranging (Università degli Studi di Siena, 2019), authors based

on the foreign research experience for evaluation of results chose calculation of criteria weights (Verly, Lidouh, & De Smet, 2011).

The invited experts compared problem pairs and evaluated the intensity level of their co-interaction in the hierarchy. Authors in this research use four level hierarchy scheme (Figure 1) (Saaty, 1987), where Level 1 (M) is the aim of the work – to find the most appropriate alternative (A), which can be done while evaluating and comparing the chained pair, Level 2 (criteria group KG), Level 3 (criteria in criteria groups KKGr) and Level 4 elements (A_n)

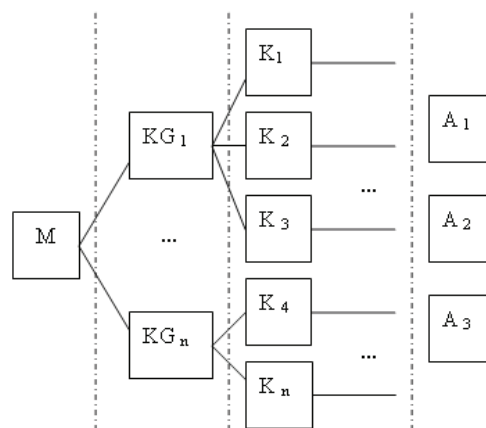


Figure 1. Four level criteria hierarchy of alternative assessment four levels based on principles of AHP method.

The assessment of relative importance of the criteria is carried out by the experts, whilst using criteria relationship importance classificatory, which is based on the basis of criteria relative importance nice point scale and includes description of each point of the scale (Bolevics, 2018).

The KG and alternative was chosen based on the theory of the research, while defining the criteria groups, which are related and those institutions which are interested in introduction of tax. The KKGr are the interests of the related groups in the introduction of the tax. The alternatives (A_n) were chosen based on analysis of the tourism tax modules in countries abroad. The criteria alternatives were chosen based on the selected basis of theory and the views expressed by experts during the interviews on the needed framework of the tax system. After filling of the hierarchy matrix a criteria weight calculation for each of the hierarchy elements was carried out, which indicates of their importance compared to each criteria of higher level.

Based on Random Index value matrix created by the AHP author T.Saaty, where the table includes average random consistency (RI) for the different size of possible matrixes, based on which it is possible to calculate the average random consistency index (RI)

values in order to acquire the balance Consistency ratio (CI). CR has to be less than 10% or 0.10, in seldom cases it can be 0.20. If CR is not within these limits, then experts have to reevaluate their assessments, or they have to redefine the task (Saaty, 1987). With respect to the General Data Protection Regulation (GDPR), which guarantees the private persons rights to privacy (Datu valsts inspekcija, 2019), expert opinions are anonymised and are described as Expert 1 (E1), Expert 2 (E2), etc.

Results and Discussion

Review of tourism tax in Europe and worldwide

Globally, the tourist tax has been named differently: pillow tax (Lithuania), eco tax (Balearic islands), bed tax (New Zealand), accommodation tax (Germany and Austria), tourist tax (Belgium, Spain and Bulgaria) and others. In Latvia, the tourist tax was defined as the *public or local government tax*, which is collected from the tourists. These can be entry, exit, hotel, resort tax, etc.

Globally, the first instance of tourism tax can be traced back to France and Italy, where in 1910 tax was introduced in the seaside resorts (Gazzetta ufficiale, 1938). Meanwhile in 1946 in the US, New York city introduced a hotel tax despite the criticism by the New York hotel association. The tourism tax exists in multiple countries, for instance, Russia, Tunisia, Ukraine (Lebedeva, 2017), Japan, New Zealand, Turkey, Peru, multiple US states including Alaska (ETOA, 2019), Bhutan (Tourism Council of Bhutan, 2018), Zambia, Canada (City council of Brandon, 2019).

In the European Union, already 18 out of 27 Member States (Table 1) have introduced tourism tax, it has not yet been introduced in Finland, Cyprus, Denmark, meanwhile in Estonia and Latvia the introduction of a nationwide tourism tax is considered. The amount of the tourism tax (Table 1) is not an obstacle for the tourists to travel to Paris, Brussels or Amsterdam (Davidson, 2018).

Table 1

Tourism tax in Europe (1994. – 2018.)

Country	Place	Tax for night per person, EUR	Tax Introduction Year
Austria	All 9 provinces	0.15 – 2.18	2010.
Belgium	Antwerpen, Bruges, Ghent	2.00 – 2.50	2016.
	Brussels	2.50 – 7.50	2017.
Bulgary	All country according to law	0.10 – 1.53	2011.
Czech Republic	Prague	0.50	2014.
France	Paris	0.20 – 4.00	1994.
	Lion	0.22 – 2.47	2010.
Croatia	-	0.21 – 0.73	2008.
Italy	81 towns and resorts	1.00 – 7.00 based on the town	2011.
Lithuania	Nering (Nida)	5.00 – 45.00	2008.
	Druskininkai	1.00	2011.
	Palanga	0.30	2012.
	Kaunas	0.50	2015.
Malta	All country	0.50 – 5.00	2016.
Netherlands	Tourism tax is introduced in 421 local municipalities	5% of the hotel room price	2006.
Poland	Tourism tax is introduced in 233 local municipalities	From 0.50 to 3.57 depending on the municipality	2018.
Portugal	Lisabon, Porto	1.01	2015.; 2018.
Romania	Bucharest	3% of the hotel room price	2012.
Slovakia	Bratislava	1.65	2017.
Slovenia	Vaneča, Fokovci, Vino, Toplice	1.01	2003.
Spain	Balearic Islands	0.50 – 2.00	2016.
	Cathalonia	0.45 – 2.25	2012.
Hungary	Budapest	4% of the hotel room price	-
Germany	Cologne, Berlin	5% of the hotel room price	2010.

While pursuing analysis of scientific literature and statistics globally and in Europe (Spain, Italy, Netherlands, Czech Republic, Lithuania, Butan, Malaysia, Zambia, New Zealand) (ETOA, 2019), where tourism tax has been introduced there has been no indication that the introduction of tax impacts the tourist flow negatively (UNWTO, 2018). Therefore, the argument that the introduction of the tourism tax could negatively impact the tourist flow cannot be approved.

Review of tourism and tourism tax in Latvia

In Latvia, the first occasion of tourism tax has been identified in 1891 when it was introduced in almost all of the resorts in Latvia: Baldone, Jurmala, Kemeris, Ogres, Sloka and Cēsis. In Jurmala, the tax was existent for the longest period of time – 129 years. Due to the complicated administrative process, the tourism tax for hotels was cancelled, but from 1996 onwards entry cost for all non-local vehicles was introduced (Latvijas Vēstnesis, 2000), that in 2019 accounted to income of 2.81 million euros. These incomes were used to promote tourism, optimum environment; improvements for development of resorts, nature protection, heritage protection, as well as for upkeep of public safety and order (Valsts kase, 2019). Trials to introduce tourism tax in Latvia have encountered fiasco in Abava heritage valley (2010) and Carnikava (2011), because it was introduced without further discussion with the private sector, which were deemed to be the sole collectors of the tax; also, neither evaluation of the tourist flows, nor analysis of the tourist impact on the environment was carried out (Puriņš, 2011).

However, in order to reduce the negative impact that is caused by extra influx of tourists, i.e., littering of the territory, damage to the tourism infrastructure, illegal vehicle movement in the dune territory, discussions were held in the Rucava municipality Pape and Nida, as well as in Pāvilosta (Baļčūte, 2017; Pāvilostas novada dome, 2018).

The tourism in Latvia as well as globally has been negatively impacted by the Covid-19 pandemics. The limited or fully stopped flow of tourists has left negative long-lasting impacts on the tourism industry. Already in May 2020 a major dive in the number of tourists was evident: the number of served local and international visitors dropped by 88.5% compared to similar period in 2019. Visitors in tourist hospitality locations stayed for 77.5 thousand nights, which is by 84.2% less than in May 2019 (CSB, 2020).

In the settings of more intense globalisation in the World and Europe, Latvia needs to utilize the comparative advantages in order to develop territories with the highest sustainable development potential. Organisation for Economic Co-operation and Development (OECD) has noted the need for

establishing the competitive advantage of Latvia in surrounding regions as one of the challenges of the Tourism Policy of Latvia (OECD, 2018). In order to pursue these activities, additional financial resources are needed and one of the means for collecting this is through the tourism tax. In Latvia, there is a certain opposition against introduction of the tourism tax (Okdaldere, 1990).

This has been portrayed throughout the interviews carried out by authors: (1) it is believed that the implementation of tourism tax would cause significant jump in accommodation service prices, which could lead to reduced competitiveness of Latvia among the Baltic States; (2) there is a disbelief in proper and translucent management of collected resources; (3) it is unclear how the collected resources will be used; (4) there is a lack of trust in conduct of public institutions; (5) the financing for the tourism sector could be allocated while taking it away from other sectors and other needs of national budget. Nonetheless, authors have to agree with the respondents that due to mismanaged functionality of the tourism tax system, it could leave negative consequences on the regional development. For instance, over the course of past years the number of available hotels has increased and the impact of shared economy has also increased. These shared systems allow to share property, skills and other assets non-profit or for profit when these assets are not fully utilised by the owners themselves (Rūse, 2017).

Approximately 10% of tourists use hospitality services offered on Airbnb or similar platforms, thus creating the so called “grey area” for proper collection of taxes and thus impacting the regional development (Airbnb LLC, 2020).

It has to be noted that administration of taxes through Airbnb and Booking.com is a collective problem of Europe. However, foreign researchers indicate that tourism sector in regions subsidised through tourism tax could ensure proper functioning and development (Rey-Maqueira, Lozano, & Gomez, 2009; Forsyth & Dwyer, 2010; Sheng, 2017).

Analysis of AHP method

In order to define the most proper type of tourism tax for regions of Latvia, i.e., first hierarchy level (Figure 1), further expert interview data of the second hierarchy level in criteria group (KG) was analysed: (1) System functionality; (2) Tourist interests; (3) Entrepreneur interests; (4) Regional (municipal) interests and (5) National interests.

In summarised assessment over all criteria groups (Table 2), the highest evaluation was given to criteria Regional (municipal) interests – 0.265, thus according to the assessment of experts, this is the most significant criteria for facilitation of introduction of tourism tax.

Table 2

Comparison of criteria groups (KG)

Criteria groups	Criteria weight (W)				
	E1	E2	E3	E4	E5
System functionality	0.16	0.19	0.125	0.19	0.24
Tourist interest	0.19	0.16	0.194	0.19	0.24
Entrepreneur interests	0.19	0.25	0.187	0.19	0.19
Regional (municipal) interests	0.25	0.19	0.265	0.25	0.13
National interests	0.19	0.19	0.177	0.16	0.19

Table 3

Criteria in Criterly Groups (KKgr) comparison from the regional (municipal) perspective

Criteria in Criterly Groups	Criteria weight (W)				
	E1	E2	E3	E4	E5
Financial resources savings	0.213	0.159	0.195	0.159	0.195
Investments in infrastructure	0.186	0.190	0.195	0.190	0.195
Increase of budget income	0.165	0.216	0.164	0.216	0.164
Development of tourism sector	0.250	0.247	0.252	0.247	0.252
Communication and improvement of the brand	0.186	0.190	0.195	0.190	0.195

This criterion is important because the local municipalities carry out the implementation and administration functions.

A significant dispersion in assessment values can be observed 0.125 – 0.265 (Table 2), which indicates of diversity in expert opinions. The second highest level of assessment was acquired by criteria Entrepreneur interests, which is important to take into account that entrepreneurs in regions would be directly involved in collection of such a tax from tourists. While assessing each criterion separately, authors concluded that when evaluating Tourist interests, dispersion is moderate, 0.16 – 0.24. When comparing with the criteria Regional (municipal) interests, the Tourist interests have moderate weight. Similarly, experts estimate Entrepreneur interests, where assessments are similar – criteria weight amplitude is 0.137 – 0.193. Taken into account the fact that tourists and entrepreneurs are the key factors in tourism tax system, the fairly similar assessment by the experts is understandable. Criteria Regional (municipal) interests is valued equally similarly by experts, the dispersion is from 0.187 to 0.19. It should be noted that interests of municipalities have been valued higher than interests of tourists.

In the third level of hierarchy when evaluating criteria groups (KKgr), they were evaluated based on the perspectives of selected groups: (1) *Tourist interest group – New tourism products*; (2) *Entrepreneur interest group – Investments in infrastructure*; (3) *Municipal interest group – Development of tourism*

industry in regions; (4) *National interest criteria group – Possible financial resources savings and increased budget income*. Within KKgr five specific criteria for each group were selected, based on the theory of the research. Taken into account that each group has its own interests, KKgr was split into two parts:

Tourist interest criteria: (1) *Investments in infrastructure*; (2) *Improvements to the nature and environment*; (3) *Sustainability of nature and environmental resources*; (4) *Cultural heritage*; (5) *New tourist products*.

Entrepreneur and municipal interest criteria: (1) *Financial resources savings*; (2) *Investments in infrastructure*; (3) *Increase of budget income*; (4) *Development of tourism sector*; (5) *Communication and improvement of the brand*. These KKgr criteria were evaluated from the perspective of criteria groups. For instance, investments in infrastructure was evaluated from the perspectives of tourists, entrepreneurs, regional (municipal) and national level.

After compiling the total assessment results from the regional (municipal) perspective, authors conclude that expert opinion is unanimous, whilst evaluating the criteria *Development of tourism sector* with minimal criteria weight disparity at 0.247 – 0.252 (Table 3). Expert assessment coherence indicator KKgr in comparison from regional (municipal) perspective < 0.10, it means a good expert coherence level. Authors believe that the results correspond with the goals of

the tourism tax introduction, thus, it also functions as a means for attracting additional financial resources to the tourism sector. The increase of income is not defined as a priority because, at the perspective of municipal administration, financial resources are only used as an instrument for development of tourism industry, not as an end in itself to collect more resources.

While carrying out the analysis of the Highland Council tax introduction strategy documentation, authors selected different types of tourism tax introduction models: (1) *Directly charged to tourists* – depending on the type of how the tax is charged from the tourist – on the border crossing, in the airport, as a charge on entry, as an exit charge, etc. (2) *Progressive tourist tax model* – tax and its amount is dependent on the size of the company. For instance, the visitors of Rome have to pay 3.00 euros per person per night, whilst staying in a two-star hotel, but 7.00 euros when staying in five-star hotel; (3) *Flat or fixed rate model*, standard costs are applied similarly for all categories of accommodation services, independent of the star rate; (4) *Tax liability model* – this model has been utilized in Brussels where the tax is dependent on the space and type of accommodation unit as well specific additional services that are included in the room suite (for instance, minibar). The tax payment can be applied evenly throughout the year or it can be season dependant allowing to cash in higher tariff tax during the high season (The Financial Scrutiny Unit of Scottish Government, 2018).

To sum up the assessment of all alternatives within the 4th level of hierarchy, the highest criteria weight was -0.359, attributed to the criteria *Fixed rate model for enterprise*. Therefore, the fixed rate – is an undefined sum of money, which is decided on by the local government and is applied to each and every visitor staying at local hotels of a given municipality.

Conclusions

Tourism tax exists worldwide for more than 100 years. The UNWTO has identified 45 specific tourism taxes. Over the period 1994–2018. the tourism tax has

been introduced in 18 out of 27 EU Member states and the costs have varied from 0,15 to 45,00 euros. Analysis of the scientific literature has indicated that introduction of tourism tax has no negative impact on the tourist flow. In Latvia, the first tourism tax was introduced already in 1891 for visitors of the resorts and had been in place in health resorts until 1942. Since 1996 an entry tax is in effect in Jurmala town, where in 2019 it brought in 2.81 mil. euro revenue, money that was further used for tourism facilitation purposes, development of resorts, improving of the public outdoor facilities, environment protection, protection of cultural heritage, as well as for upkeep costs, public order and security service costs. Challenges in introduction of tourism tax in Abava valley (2010) and Carnikava (2011) were caused by shortcomings of public communication with the stakeholder groups, tourist flows, and neglect of the impact on environment. The increase in tourist flows and their impact on environment brings up the question of introducing a tourism tax in several regions, incl. Pape and Nida in Rucava county as well as in Pabilosta county. Meanwhile, the negative impact of Covid-19 pandemic causes serious financial hardship to the tourism industry and thus creates need for more financial resources, which could be attracted in the form of tourism tax. The conducted expert interviews revealed that: (1) there is a common belief that introduction of tourism tax could drive up prices of accommodation service thus hampering the competitiveness of tourism industry of Latvia in the Baltic region; (2) there is a disbelief in proper and translucent management of collected resources; (3) it is unclear how the collected resources will be used; (4) there is lack of trust in conduct of public institutions; (5) the financing for the tourism sector will be allocated from other sectors and other needs of national budget; (6) the tax could negatively impact the market through increased rates of transactions in the “grey area”. According to experts’ opinion voiced through AHP methodology approach, the introduction of the *Fixed rate model for enterprise* was chosen as the most appropriate model for Latvia.

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APPROBATION OF PROJECT MANAGEMENT METHODOLOGY IN DEGRADED AREAS REVITALIZATION PROJECTS

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Abstract

Degraded areas are an important element of modern urban space. This is especially evident in industrial post-socialist countries, including Latvia, where intensive industrialization took place during the 20th century. Regeneration of degraded areas is an opportunity not only to prevent pollution caused by the effects of past industrial activity, but also to improve the urban environment, develop business and take care of the overall image of the urban landscape. One of the tools that local governments in Latvia and also in the European Union (EU) can use to return degraded areas to economic circulation is to implement the opportunities offered by European Regional Development Fund (ERDF) projects by absorbing funding from the Operational Program "Growth and Employment" 5.6.2 within the framework of the specific support objective "Revitalization of territories by regenerating degraded territories in accordance with integrated development programs of local governments" (SSO 5.6.2). In order for the project implementation to be successful and to be able to achieve the project goal, the local government, as a project implementer, needs to choose a project management methodology appropriate for a specific project.

Key words: degraded areas, project management methodology, revitalization projects.

Introduction

The existence of degraded areas in Latvia is a relatively new type of land use problem that began to develop in the 20th century and is still ongoing. The main reason for the existence of degraded areas is the change of the political system in Latvia, when after the collapse of the Soviet system abandoned, non-functioning factories, production facilities appeared, causing the emergence of degraded areas (Berzina *et al.*, 2019).

In Latvia, the definition of degraded area is set out in the Land Management Law, which states that "degraded area – an area with ruined or damaged topsoil or abandoned building, mining, economic or military activity area". The law stipulates that each local government develops its own assessment of the possibilities of using its territory, but does not determine a common approach in the criteria and definition of degraded area. In the international literature, the term "*brownfields*" is mentioned, which describes a certain problem of urban development – a post-industrial area that arises as a result of various anthropogenic activities and is located in urban centres (Yount, 2003).

Land is a limited resource. In order to ensure the sustainable development of the territory of each municipality, the focus of activity should be on more efficient use of land as a resource. Regeneration of degraded areas is an opportunity not only to prevent pollution caused by the effects of past industrial activity, but also to improve the urban environment, develop business and take care of the overall image of the urban landscape. Latvian local governments can apply for support from EU funds, which is introduced in SSO 5.6.2 and the aim of this program is the revitalization of territories by regenerating degraded areas in accordance with municipal development

programs, ensuring environmentally friendly and environmentally sustainable territorial growth and job creation (Cabinet of Ministers Regulations, 2015). In order for the local government to be able to implement projects professionally, in accordance with the specifics and requirements of the project, it is necessary to choose an appropriate project management methodology.

The aim of the study is to analyze the Waterfall and Agile project management methodology and to evaluate the possibilities of their adaptation in the implementation of degraded areas revitalization projects. To achieve this, the following specific tasks are set:

- 1) to analyze the theoretical aspects of Waterfall methodology;
- 2) to analyze the theoretical aspects of Agile methodology;
- 3) to analyze SSO 5.6.2 project program requirements;
- 4) to adapt methodologies for the implementation of degraded areas revitalization projects.

In this study, the term "approbation" means "recognition in favour" as defined in the glossary of terms and foreign words. The scientific article provides a basis for further research on the application of different project management approaches and methodologies, which could be based on the idea of creating a unique methodology for a degraded area revitalization project.

Materials and Methods

The following methods were used in the study:
1. Document analysis. Taking into account the research object – revitalization projects of degraded areas, as well as the aim of the research, this method can be considered as one of the most suitable methods for

obtaining and analyzing information. The regulatory enactments regulating SSO 5.6.2 were analyzed – November 10, 2015 Regulations of the Cabinet of Ministers No. 645 “Operational Program” Growth and Employment “5.6.2 Specific Support Objective” Territorial Revitalization by Regenerating Degraded Areas in Accordance with Local Government Integrated Development Programs and Guidelines No. 2.1 “Guidelines for Determining Eligible and Ineligible Costs in the 2014-2020 Planning Period” developed by the Ministry of Finance. Document analysis was used with the aim to find out what requirements local governments must comply with when implementing projects within the framework of the SSO 5.6.2 program. The guidelines have been developed with the aim to explain the types of eligible and ineligible costs and the basic principles that determine which types of costs can be included in the projects of the EU Structural Funds for 2014–2020 planning period. The information obtained in the document analysis provides an opportunity to evaluate the choice of the appropriate project management methodology. 2. Analysis of theoretical literature sources. This method has been chosen to perform an analysis of the project management methodologies available in project management theory using the available literature sources. In project management theory, two basic project management methodologies are distinguished – Waterfall and Agile (Agile methodology also includes other methodologies – Scrum, Kanban, XP, etc.). Using the comparative approach in the analysis of theoretical literature sources, the comparison of both methodologies, analysis, compilation of the obtained data were

performed. Based on the obtained data, an approbation model of both methodologies was developed in the management of degraded areas revitalization projects in municipalities. The analysis of theoretical literature sources is based on scientific publications, conference proceedings, project management books.

Results and Discussion

The choice of the best project management methodology is based on the characteristics, requirements, external environment in which the project will be implemented and organizational aspects. Due to the differences between the projects and the fact that the projects are implemented in conditions of uncertainty, it is necessary to choose the appropriate methodology for the management of each project.

Project management methodology is defined as a set of methods, techniques, procedures, rules, used to achieve project objectives (Spundak, 2014). The methodology is based on specific project requirements and ensuring its successful management. The definition of project management methodology includes aspects of standardization of organizations and project management activities to achieve the project goal (Zdanyte & Neverausks, 2011). As no two projects are the same, even if they are implemented within the same program and the same organization, the choice of the appropriate methodology can be problematic, as there is no one general project management methodology that is suitable for all projects in the same field of activity.

Latvia’s municipal strategies for revitalizing degraded areas with the support of EU funds are

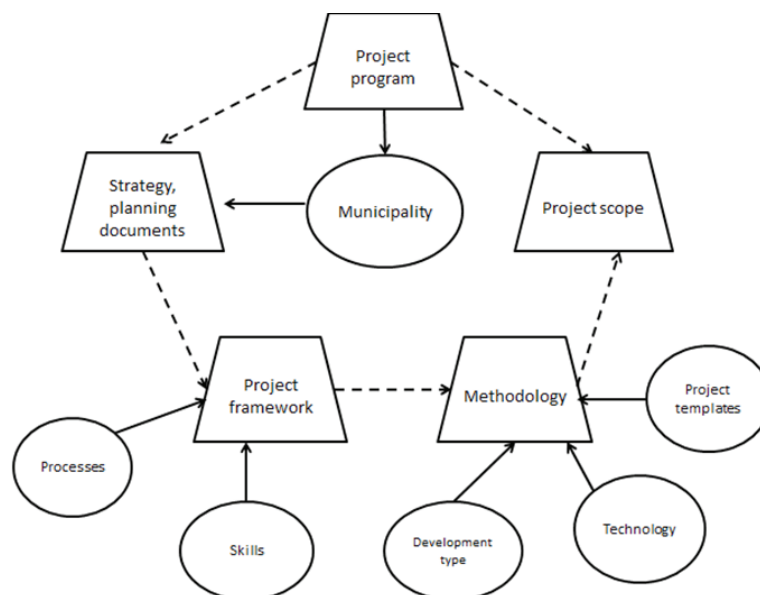


Figure 1. A conceptual model to justify the choice of project management methodology in municipalities.
Source: author’s created by Jason Charvat, 2003.

mostly related to business development, in which projects are adjusted for innovative sectors and new economic development trends. The success of the project and the project results according to the needs of the entrepreneur depend on the quality of the project management process ensured by the project management methodology. In order to clearly demonstrate the need for project management methodology and substantiate its role in the municipal development process, the author has created a scheme that depicts the elements of this process and the link between them (Figure 1).

The diagram shows a conceptual model that substantiates the role of project management methodology in the structure of municipal project-oriented activities. At the heart of the project management methodology for the municipality, as a project implementer, is an effective strategy influenced by project programs and development planning documents. In accordance with the municipal planning documents, the project framework and methodology are determined, which consists of the selected technologies, developed samples and templates for documents.

Projects are unique, so it is necessary to choose the best model for their management, based on the most important factors determined by the project requirements and the project selection conditions set by EU funds.

The trend for organizations to change their way of thinking, philosophy and culture is growing, and this is also having an impact on project management, introducing new, innovative solutions that help achieve the desired result and fostering the implementation of organizational strategies based on successful project management. So the question is – which of the project management methodologies should be used and what criteria make you choose one of the methodologies? This issue is especially relevant for degraded area revitalization projects, as the result of such projects must meet not only the requirements and needs of the municipality as a project implementer, but above all, the end user of the project – an entrepreneur who will develop the potential of this area with his or her business idea.

By their scope, degraded areas projects are infrastructure development projects. As mentioned in the literature, for example, Mike McCormick's "Waterfall vs. Agile Methodology", the Waterfall methodology is more suitable for infrastructure projects, which states that it is a linear project management approach, where the requirements of stakeholders and customers are summed up at the beginning of the project, and then a sequential project plan is created to adapt to these requirements. This methodology is called Waterfall, because in this

model the tasks are performed sequentially – the amount of resources and the time allotted for each task are carefully planned. Project management in this case follows the project life cycle model. As a result of this close adherence to the engagement plan, there is often a risk that significant factors have not been included in the plan, and this may result in errors for which resources are not allocated. After each phase, documentation is prepared to ensure the quality of the project. Although the Waterfall methodology highlights its stability as one of its advantages, stating that it can be applied equally to all projects, it is increasingly cited as one of the main disadvantages of such an approach. Nowadays, more and more authors emphasize the fact that one approach does not suit everyone (Wysocki, 2007). Projects, like the business environment, are becoming increasingly complex and dynamic, and digitalisation processes are evolving rapidly, requiring not only changes in management styles but also adaptation to the rapidly changing external environment of projects. Waterfall project management methodology is based mainly on hierarchy and linear task relationships, which prevents the possibility to change the tasks planned in the project (Spundak, 2011).

To address the shortcomings of the Waterfall project management methodology in terms of a flexible and dynamic approach to project implementation, the Agile project management methodology was developed. Agile methodology is based on its 4 basic principles, which emphasize – "individuals and interactions over processes and tools, working software over comprehensive documentation, customer collaboration over contract negotiation, responding to change over following a plan" (Apke, 2015). It should be noted that these principles are not categorized - unequivocally emphasizing only those statements that determine the essence of Agile principles – individuals and interactions, working software, customer collaboration, responding to change. Agile methodology does not deny and even partially accepts processes and tools, comprehensive documentation, contract negotiation, following a plan. It should be noted that these principles are not categorized: by emphasizing the statements on the left, no less important role is delegated to the statements on the right. The above shows that Agile emphasizes a customer-oriented approach – as little contractual commitment as possible, but more cooperation with the customer, leaving following a plan and project requirements in the background. The Agile methodology, like the Waterfall methodology, offers the phasing of the project process (Wysocki, 2012), which improves the transparency of its processes. Since this methodology was originally developed for the creation and implementation of

Table 1

Difference between Waterfall methodology and Agile methodology basic criteria

No	Criteria	Waterfall methodology	Agile methodology
1.	Requirements	Clearly defined, do not allow changes	Not fixed, adjust to change
2.	Users of the project result	Not involved	Close cooperation
3.	Documentation	Extensive volume, processes are documented	Primary necessity documents
4.	Planning	Planning is the most important stage of the project	Does not attach much importance

Source: created by the authors based on Spundak, 2012.

information technology projects, over time it has begun to be used in both engineering and construction projects. However, it should be noted that using an Agile methodology based on the Agile philosophy and way of thinking can only yield positive results for those organizations whose culture is in line with the Agile philosophy (Apke, 2015). In this case, there may be more discussion not about the use of the Agile methodology itself in degraded areas revitalization projects, but about the readiness of the municipality as an organization to change its internal culture to adapt it to the possible use of the Agile methodology.

Summarizing the findings of the analysis of the theoretical literature, the data are presented in the table, which shows the main differences in the use of both methodologies based on criteria that are relevant for degraded areas revitalization projects – requirements, project result users, documentation, project planning.

As the information summarized in the table shows, the two methodologies can be considered different in all the criteria, which are set as the most significant in degraded areas revitalization projects. This shows that unambiguously choosing the appropriate methodology in project management is a complex process with inherent challenges. Especially in EU funds projects, which have strict requirements from the managing authority of EU funds and co-operation institution.

Both the Waterfall project management methodology and Agile have their advantages and disadvantages, and it is difficult to assess which of the methodologies is better (Andersen, 2006). The Waterfall methodology is more suitable for projects with well-defined initial requirements and a clear project goal, but with a low level of adaptation to change (Wysocki, 2007), while the Agile methodology is based on fast and flexible adaptation to changes in circumstances of great uncertainty.

Before choosing one of the methodologies and adapting it to the degraded areas revitalization projects implemented by local governments, it is first necessary to get acquainted with and evaluate the project program guidelines and regulations. As mentioned above, one of the support instruments in the revitalization of degraded areas is the use of EU funding project

financing opportunities, which is regulated in SSO 5.6.2 within the framework of the program and the implementation of which in Latvia based November 10, 2015 Cabinet Regulation No. 645 “Operational Program” “Growth and Employment” 5.6.2. Regulations for the Implementation of the Specific Support Objective “Revitalization of Territories by Regenerating Degraded Areas in Accordance with Municipal Integrated Development Programs”, aimed at the revitalization of territories by regenerating degraded areas in accordance with municipal development programs, ensuring environmentally friendly and environmentally sustainable territorial growth and job creation. The regulations prescribe the indicators to be achieved as a result of the project, the activities to be supported and the available funding, as well as the conditions regarding the cooperation partner - entrepreneur, who will be the user of the project result as a result of the project implementation under this project, the entrepreneur has to make a commitment to use and maintain the project result and must provide proof that he undertakes to create new jobs and invest in his or her intangible assets and fixed assets as a result of the project.

Within the framework of this project program, investments in the renewal of territories are supported, which will be adapted for the location of new companies or the expansion of existing companies in order to promote employment and economic activity (Cabinet of Ministers Regulations, 2015). This shows that the main area of project activity is the development of infrastructure with a high level of complexity.

In complex construction projects in the field of infrastructure, time, resource and cost planning is important in project management. Infrastructure projects have largely taken a requirements- and control-oriented approach, but recent research suggests that complex projects require more flexible practices to manage unavoidable project changes. However, the impact of flexibility-oriented project management on the results of complex projects has not been rigorously empirically tested in the past (Eriksson, 2017).

Taking into account the specifics of degraded areas revitalization projects and using the data in Table

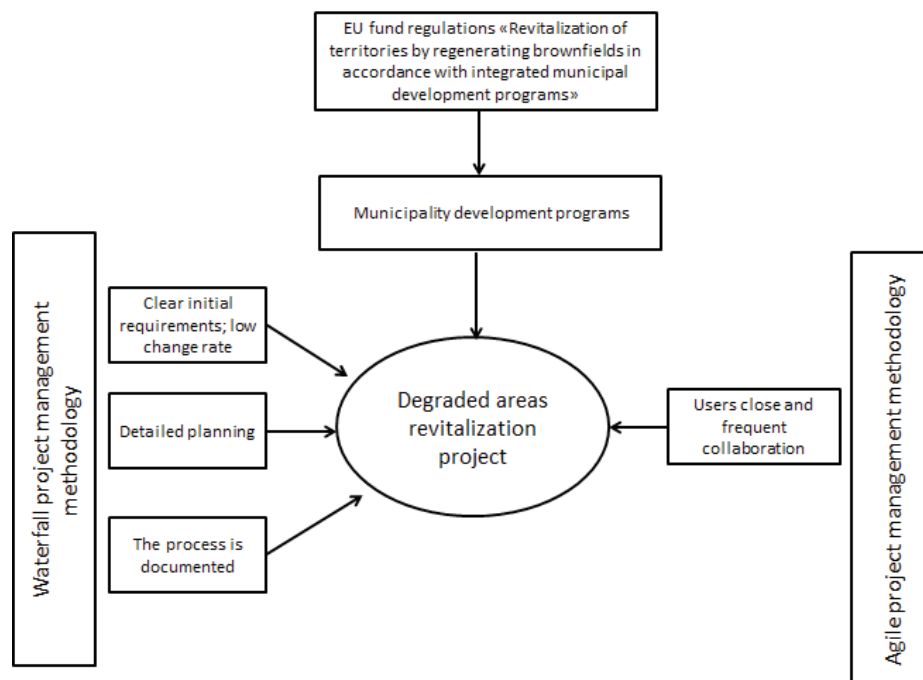


Figure 2. Approbation model of Waterfall and Agile methodologies in degraded areas revitalization project management in municipalities (created by the authors).

1, it is possible to evaluate the possibility of using the necessary project management methodology. The authors emphasize the basic criteria in the implementation aspects of this project program, which is careful and detailed planning to ensure achievable indicators, funding and define project activities, entrepreneur involvement in project implementation and definition and control of project requirements. When setting requirements for a project, it is necessary to document them, which is also determined by the EU funds co-operation institution and the guidelines for the implementation of EU funds projects. No less important role in degraded areas projects, especially in the context of SSO 5.6.2 framework, is played by the user of the project result - the entrepreneur, who obliges the municipality to create a project solution that satisfies the requirements and needs of the entrepreneur. This suggests that the entrepreneur should be involved in the implementation of the project and that his requirements should be decisive. The organizational form of municipal work in ensuring project management stipulates that the project management team is formed from the municipal administrative resources and municipal project employees are involved in the project management team. Project implementation working groups include staff who directly participates in the implementation of the project – the contractor, the author’s supervisor, the cooperation partner and other stakeholders. In this case, the user of the project result, i.e. the entrepreneur, may be involved in the implementation

of the project, but his participation will be more engaging but not decisive and decision-making. Such a procedure is determined by each local government, in accordance with the specifics of the project, and it does not contradict the existing regulatory enactments in Latvia and SSO 5.6.2 regulatory documents.

Evaluating all aspects that are able to ensure successful project management in degraded areas revitalization projects, the authors have developed a methodological framework for degraded areas projects, which is shown in Figure 2. Based on the data of Table 1 and the requirements of the project program, it is possible to create an approbation model of the degraded areas revitalization project methodology.

As shown in Figure 2, in the management of degraded areas revitalization projects, it is important to know and manage the requirements set by the EU funds project program, project quality and scope regulatory requirements, project regulatory requirements, and develop detailed plans. All of the above activities are relevant to the Waterfall methodology. As an important factor in the implementation of these projects is the involvement of the user of the project result, i.e. the entrepreneur, this approach can be implemented using the Agile methodology in the management of degraded areas revitalization projects. Thus, it can be argued that one methodological approach to the implementation of degraded areas revitalization projects may not be enough - more effective results can be achieved using different elements of both

methodologies. It is important to find the main factors from both methodologies and test them according to the specifics of the project.

Conclusions

1. In view of the above, it can be argued that the methodologies analysed are different in nature and offer a different approach to project management. In accordance with the tasks set, it can be concluded that:
2. Waterfall defines strict requirements, documented processes and is suitable for projects that do not envisage a flexible approach and adaptation to change. The specifics of infrastructure projects are in line with the guidelines of the Waterfall methodology. However, it should be kept in mind that projects are implemented in a rapidly changing environment, which must be able to adapt to the requirements of the external environment, and this makes it difficult to choose such a methodology in all the basic criteria.
3. The Agile methodology offers a flexible approach during project implementation, cooperation with the client, who is the main stakeholder of the project, as little documentation and contracts as possible. The methodology envisages effective adaptation to new conditions and changes during the project implementation, which is characteristic of the specifics of modern project management in infrastructure projects as well.
4. Strict and certain requirements for the management of degraded areas revitalization projects are determined by the regulatory enactments regulating SSO 5.6.2. The requirements mainly relate to project activities, funding, result indicators, which indicate the need for detailed planning and extensive documentation in the project - contracts, technical documentation, financial plan, time schedule, detailed cost reports. All project documentation is checked in the EU funds co-operation institution, and its scope and type is determined by the guidelines developed by the EU funds responsible institution.
5. Each of the methodologies is suitable for projects of a different nature, scope and size, but this does not mean that a successful project result can be achieved using only one of the methodologies. In order to choose an appropriate project management methodology, it is first necessary to determine the specific conditions of each project and the factors on which the project implementation is based. Therefore, it is recommended to choose the methodology based on the criteria determined by the content of the project and the planned objectives.
6. Municipalities form project management teams based on their human resources, which are managed by a project manager appointed by order of the head of the municipality. The entrepreneur who is interested in the outcome of the project may be included in the project implementation working group. It should be emphasized that the entrepreneur's role in the management of this project is important, and the project result must be in line with the needs of the entrepreneur.

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ATTITUDES OF POPULATION TOWARDS THEIR WELLBEING AND CLIMATE CHANGE INTERFACE: TERRITORIAL DIMENSION

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Abstract

This article discloses wellbeing and climate change interface issue that becomes a challenge in many countries of the world. Furthermore, attitudes of population about their wellbeing and how it is related with climate change is still developing topic in social sciences. Wellbeing of population is affected by various factors, both positive and negative, but impact of climate change is growing and affects various spheres of human life, despite where they live. Accordingly, the research problem was formulated – how wellbeing evaluations of Lithuanian population are related to climate change. This article aims to disclose wellbeing perception of the Lithuanian population in the context of climate change based on the territorial dimension. European Social survey (ESS) Round 8 and Round 9 data were used for the research, comparison method was applied. Findings showed that perception of wellbeing (happiness and satisfaction with life) and its evaluations in relation to climate change are mostly positive and vary on average between 5 and 7 scores, while correlation between wellbeing and climate change variables are very weak. It should be pointed that wellbeing research at individual level can and should be as a keystone of climate change mitigation research as it shapes the state of all society wellbeing.

Key words: population, wellbeing, climate change, territorial differences.

Introduction

Climate change is understood as a challenge for today's society, its health and overall wellbeing. Furthermore, wellbeing, climate change and their interface are the biggest issues which are monitored and evaluated in sustainable development processes. Wellbeing of population in social sciences is analysed in various ways, but subjective wellbeing as non-income measure and the attitudes of the population itself towards both environmental change in general and climate change are still too little studied (Grün & Grunewald, 2010; Mkrtychyan *et al.*, 2018; Healthy environment..., 2019). Wellbeing research has an important role in the discourse of climate change, as concepts of human need and quality of life naturally overlap with the everyday uses of energy and resources within society reflecting the 'demand-side' of climate mitigation (Lamb & Steinberger, 2017). Human wellbeing is a complex concept, because it involves separate, but often used interchangeably notions of what a good life is: happiness, quality of life, welfare, standards of living, etc. These various approaches of wellbeing lead to the idea that human wellbeing perceptions become a key phenomenon for measuring and promoting good lives and a good society. As emphasized by different authors (Grün & Grunewald, 2010; Corner, Markowitz, & Pidgeon, 2014; Mkrtychyan *et al.*, 2018), background for assessment of wellbeing includes mostly subjective (individual) approach: happiness and satisfaction with life assessments, the presence of positive / negative mood, emotions. These elements are related to humans' different life domains as well as it reveals attitudes to climate change.

Questions concerning the interface among wellbeing, climate change and subjective health are

deeply analysed by various scientists (Thomas *et al.*, 2014; Lamb & Steinberger, 2017; Healthy..., 2019). Clean nature is a key factor in ensuring public health, reducing disease and promoting good health and wellbeing. Poorer communities often live in conditions of higher pollution, noise and high temperatures, and their vulnerability to environmental determinants of health is only increasing due to pre-existing health problems. The mentioned authors accept the twofold idea: on the one hand, climate change is caused by human influence and depends on climate change adaptation and mitigation strategies, on the other hand, human health and overall wellbeing in different ways are affected by environmental issues and climate change.

The spatial/territorial aspect is also important in assessing the state of wellbeing, as people in different areas may have different perceptions and assessments of climate change processes and their own responsibilities for climate change due to the characteristics of the living environment. Some literature explores the importance of territorial dimension related to wellbeing and climate change, emphasizing that some regions are more vulnerable than others (Mendelsohn, Dinar, & Williams, 2006; Grün & Grunewald, 2010; Thomas *et al.*, 2014). In addition, the deepening environmental awareness and concerns show that today's society is increasingly interested in environmental changes, which show their desire to take more care of the environment, conserve resources and thus contribute to their higher wellbeing. People's knowledge about the climate change issue is also very important, because it shows their way of thinking and discloses potential actions (Lamb & Steinberger, 2017; Taddicken, Reif, & Hoppe, 2018).

Moreover, this means that subjective knowledge and subjective perception of wellbeing and climate change issue can be central in analysing their interface.

Regarding the idea of the article, it is very obvious that various questions can be formed which relate to individual wellbeing and climate change: how much I think about the issue; how I can contribute to save environment and reduce climate change; what the best activities or tools to mitigate the climate change are; how I can put together and influence others to reduce climate change. As IPCC (2014) and Lamb & Steinberger (2017) explored, wellbeing concept is highly related to questions of inter-generational justice, including the equalization of life prospects between current and future generations which is a major topic of sustainable development including climate justice and ethics. On the other hand, some people already believe in what they do and that they do right things, act to protect environment and contribute little by little to climate change mitigation. The climate change belief reflects personal norms, which can be quite different concerning social-demographic profile of residents (like internal factors) and what attitude is shaped by external factors (e.g. national policy role, economic and environmental factors) or even it is strongly related to individual engagement with climate change (Corner, Markowitz, & Pidgeon, 2014; Thomas *et al.*, 2014). This idea was strongly justified in ESS Round 8 module “Public Attitudes to Climate Change, Energy Security, and Energy Preferences” (European Social Survey, 2016), and there was mentioned that more a person is thinking he/she has done on climate change, stronger the relationships appear between his/her believes, expectations, actions.

According to mentioned above, there was formulated *research problem of the article* – how wellbeing evaluations of Lithuanian population are related to climate change. *The research object* – perception of population wellbeing in relation to climate change. *The research aim* – to disclose wellbeing perception of the Lithuanian population in the context of climate change based on the territorial dimension. The structure of the article is as follows: *firstly*, research materials and methods are detailed, *secondly*, research results based on ESS Round 8 data are presented, finally, conclusions are presented.

Materials and Methods

Methods. As Taddicken, Reif & Hoppe (2018) emphasized, it is not easy to determine what to measure and how, because the topic climate change in correlation with wellbeing is not easy to analyse and methods depend mostly on researchers. Common research methods were used: literature analysis and synthesis, descriptive analysis, comparative method, statistical methods (Pearson Correlation coefficient),

graphic representation. These methods are interrelated and supplement each other.

Materials. In order to evaluate the wellbeing interface with climate change issue, the data from European Social Survey (ESS) the Round 8 (2016 year) and Round 9 (2018 year) were used. ESS is an international survey that has been conducted across Europe since its establishment in 2001, implemented every two years; face-to-face interviews are conducted with newly selected, cross-sectional samples (About..., 2020). It must be noted that the issue about climate change was the rotating module in ESS Round 8, and in Round 9 only one question related to care for nature and environment was left. Such situation does not allow to compare the data from a different year, but still shows how respondents value the environmental issues. This research is based on the respondents' attitudes towards several questions:

- 1) *Questions used in both ESS Rounds.* Subjective perception of respondents' wellbeing, e.g., how they themselves value / perceive the wellbeing, happiness, or satisfaction with their lives; the focus is on issues related to the concept of a good life (*evaluation is scores, in 0-10 scale*):
 - *In general, are you satisfied with your current life?*
 - *In general, are you happy?*
- 2) *Questions related to climate change in ESS Round 8 (2016 year):*
 - *How worried are you about climate change?*
 - *To what extent do you feel personal responsibility to reduce climate change?*
- 3) *Question/statement related to nature and environment in ESS Round 9 (2018 year):*
 - *Important to care for nature and environment.*

Sample. Sampling in ESS is described following the country level patterns. General requirements for the sample are given in ESS national page with the sampling principles (Sampling..., 2020). The sample for Lithuania was 2122 respondents in ESS Round 8 (in 2016) and 1835 respondents in Round 9 (2018). To have more detailed view of the topic concerning territorial dimension, the place of residence was used combining “A big city” + “Suburbs or outskirts of big city”, Town or small city and combining “Country village” + “Farm or home in countryside” (Table 1).

It is seen from the table that structure of respondents in separate Rounds have changed. There was much bigger percentage of respondents from “Country village+Farm or home in countryside” and significantly less respondents' from “A big city+Suburbs or outskirts of big city” in Round 9 comparing to Round 8.

The novelty of this research is based on the fact that attention to territorial dimension is important, but there are not many international researches where you can

Table 1

Sample size in ESS Round 8 and Round 9

Place of residence	ESS Round 8		ESS Round 9	
	N	Structure, %	N	Structure, %
A big city+Suburbs or outskirts of big city	887	41.8	482	26.3
Town or small city	746	35.2	549	30.0
Country village+Farm or home in countryside	489	23.0	801	43.7
<i>Total</i>	<i>2122</i>	<i>100.0</i>	<i>1832*</i>	<i>100.0</i>

* The total sample was 1835, excluding 3 respondents who were Missing.

focus on wellbeing and climate change interface. ESS data enable to analyse the formulated research problem and to make insights about the future of this field research. Furthermore, the issue and data analysed in this article can be easily applied in the cases of other countries which participate in ESS. As territorial dimension is not always taken in account in wellbeing research – these data enable to clarify this situation.

Results and Discussion

Following the discussions in science and specific research about wellbeing (Kozlova *et al.*, 2015; Eurofound, 2019), it is observed that territorial dimension is often left aside. Such position challenges the need to turn attention to how wellbeing is evaluated by residents living in different places of residence. Following the methodology part, wellbeing in ESS is evaluated answering two questions based on satisfaction with life and evaluation of happiness (Figure 1 and Figure 2).

Data analysis revealed that both in Round 8 and in Round 9, there were more respondents who were more

satisfied with life than dissatisfied. In both Rounds, more respondents rated their satisfaction with life at 7–9 scores. This suggests that due to various factors, people view their lives positively enough, no matter where they live.

The same is true for the respondents who live in rural areas although it is often emphasized that their attitude to wellbeing is lower. On the other hand, it is seen that in Round 8, quite a big number of respondents explored 5 scores – this shows their doubts, or no opinion about their wellbeing.

Data about the attitude to personal happiness are also more positive than negative. In both Rounds, we see that respondents indicated a high enough score of 7 or 8. Although happiness is more associated with emotions and positive events at some point in life, the results suggest that residents may feel happy living in city, town or rural areas. It should be noted that in Round 9 there were significantly more respondents from rural areas than in Round 8, so the assessments of rural respondents show, in a sense, that the rural population also becomes happier. It can be assumed

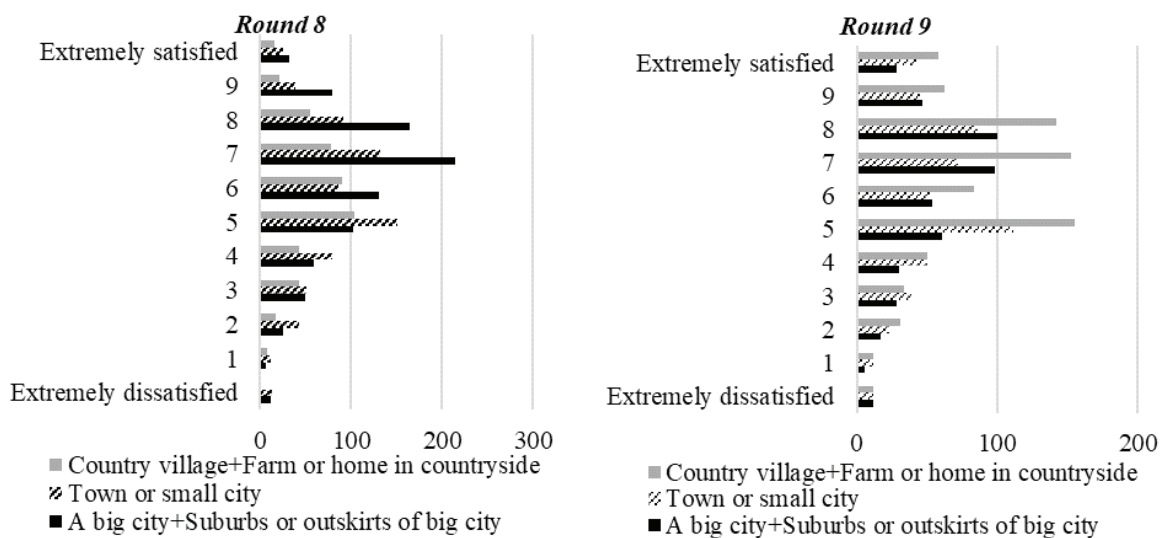


Figure 1. Respondents opinion about how they are satisfied with life as a whole according to place of residence (in scores).

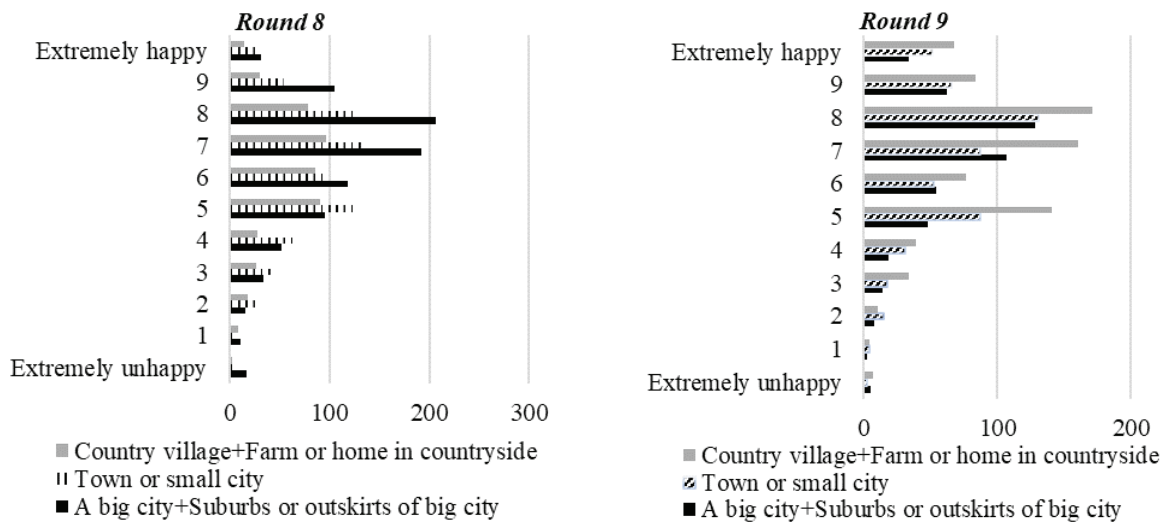


Figure 2. Respondents opinion about how they are happy according to place of residence (in scores).

that such positive evaluations of happiness are closely related to sufficiently high evaluations of satisfaction with life. Some close results connecting importance of place of residence and wellbeing were mentioned in the works of Mendelsohn, Dinar & Williams (2006), Grün & Grunewald (2010), Thomas *et al.* (2014).

Following the data from ESS Round 8 about respondents' feelings and personal responsibility to reduce climate change according to place of residence, some interesting results were found (Table 2).

The Table 2 shows that personal responsibility to reduce climate change according to the place of residence is indeed important for those who score higher, no matter where they live. In all residential

areas, respondents mostly scored 5–8 points. Those who said “A great deal” when they feel personal responsibility to reduce climate change were mostly in Town and small city, and those who said “Not at all” were mostly in cities. However, it was also noticed that in most places of residence 0–4 points were indicated by a significant number of respondents. This allows to state that the place of residence and the environment are important for those respondents who tend to act in a way that seeks to mitigate climate change possibly due to their overall wellbeing.

Respondents (data from ESS Round 8) personal responsibility to reduce climate change is closely related to how they are worried about climate change.

Table 2
Respondents attitude to what extent they feel personal responsibility to reduce climate change according to place of residence (in scores)

Evaluation (scores)		A big city+Suburbs or outskirts of big city	Town or small city	Country village+Farm or home in countryside	Total
To what extent you feel personal responsibility to reduce climate change	Not at all	54	43	22	119
	1	59	34	25	118
	2	68	43	34	145
	3	78	48	47	173
	4	84	39	31	154
	5	129	106	76	311
	6	102	80	57	239
	7	84	103	56	243
	8	44	76	34	154
	9	15	34	7	56
A great deal		29	38	17	84
Total		746	644	406	1796

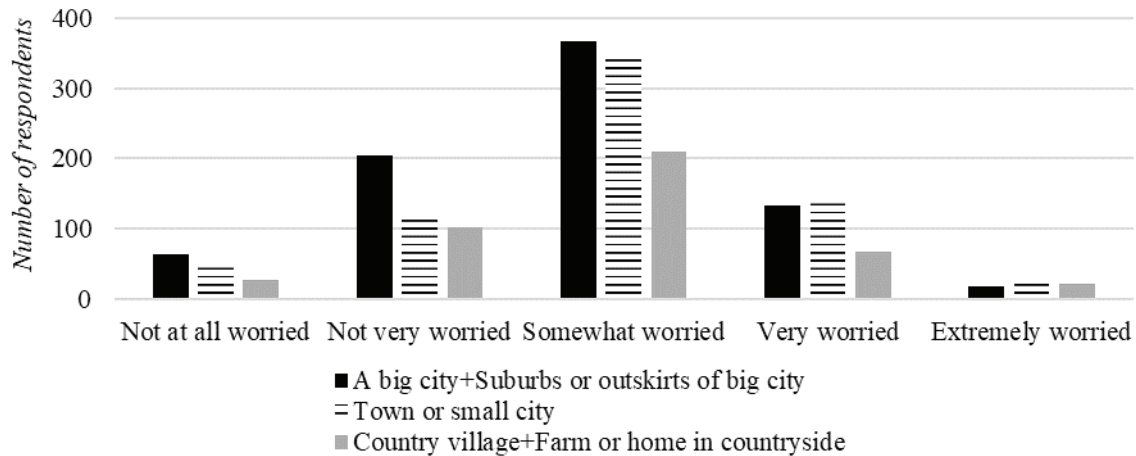


Figure 3. Respondents' attitude to how they are worried about climate change according to place of residence (own elaboration).

Accordingly, it was intended to establish the role of place of residence (Figure 3).

Distribution of respondents' attitude shows that there were more worried people than not worried about the climate change. Equally 27% of respondents living in cities and towns pointed that they tend to be more concerned about climate change. In rural areas, there were 16% of such respondents. So far, such assessments suggest that until a person personally feels the effects of climate change, their attitude towards climate change is indifferent, or he / she does not know what effect it is feeling. However, most who are aware of the impact of climate change on society realize that it is everyone's priority and responsibility to care for nature and the living environment. These insights are supported by previous research (Grün & Grunewald, 2010; Corner *et al.*, 2014; Taddicken *et al.*, 2018).

The data from ESS Round 9 disclosed that respondents who are more satisfied with life (their satisfaction with life is 6 and more scores) they tend to show they are more concerned about preserving the environment. Even 80 percent of respondents explored that their wellbeing is linked to a positive attitude towards nature and environment. The rest did not put much attention if their wellbeing and care for the environment are related. This suggests that the more respondents are conscious, the more their wellbeing and health are important to them, which directly concerns the protection of the environment. Moreover, the analysis revealed that respondents with good and fair health status care more about the nature and environment compared to others. These respondents pointed that this is "very much like me" or "like me" and nature seems to be an important factor for their life. It became clear that respondents with lower evaluations about their health also do not really focus deeply on caring for nature and environment. Such results mean that how much respondents care

about their personal health and wellbeing determines their attitude to the surrounding environment.

Pearson Correlation coefficient in both Rounds for identifying the relations between wellbeing (satisfaction with life and happiness) and different variables like climate change, care for nature and environment, subjective general health as well as place of residence was calculated.

In both Rounds, correlation between place of residence and satisfaction with life and happiness was observed negative and very weak. This implies that wellbeing variables are more affected by other factors than the place of residence. Correlation between worries and personal responsibility about the climate change revealed positive, but also very weak relations. Such a situation can be explained by the fact that not all people are concerned about the problem of climate change in the same way, and this problem is more often exacerbated when it affects them personally or their well-being in general. Wellbeing and subjective health relations were identified like negative and weak. This suggests that whether to feel happy or satisfied with life – subjective health is not the only factor, but if health status significantly worsens or improves – wellbeing evaluations will reflect this situation as well. Furthermore, as Thomas *et al.*, (2014) explored, wellbeing and climate change are just beginning to be considered as closely inter-related issue, and there is a need to discuss it not only in subjective evaluations level, but also even in political agenda, because it concerns the whole society. There was observed positive and average correlation ($r=0.512$) between feeling of responsibility to reduce climate and worries about climate change. This can be assumed as positive change in respondents' mindsets and potential actions - as it shows the growing understanding that every person is individually responsible for the environment where they live.

Following the data in Round 9, it was observed that correlation between satisfaction with life and happiness was the same like in Round 8 – it was positive and strong ($r=0.7$). Such stable situation reveals that emotional level of a person is closely related to objective factors of current life or if a respondent feels happy so his/her satisfaction with life will also be valued higher. Correlation between wellbeing and subjective general health was identified like negative and weak – the same like in Round 8. Observing the correlation between satisfaction with life and happiness and care for nature and environment, it was negative and very weak. These results seem to be quite disappointing and strange, because personal feelings about happiness and responsibility to care for nature and environment were almost denied.

The findings from the research suggest that the analysed object still needs more attention and more various analysis based on interface between wellbeing and climate change. Moreover, it is important to examine not only the theoretical claims about wellbeing and climate change in general, but include more concrete factors affecting this interface. Controversary observation that territorial dimension is often neglected in research about wellbeing and climate change interface was found. On the other hand, territorial dimension is considered as not the most relevant factor affecting wellbeing and climate change directly. The former insights were supported by Thomas et al. (2014) and Healthy... (2019), who also stated that it is vital to recognise both positive and negative climate change adaptation and mitigation experiences that can be socially and spatially differentiated and can have serious implications for health and wellbeing.

Conclusions

1. The notion of wellbeing is diverse and broad in scope; therefore, it is clear that personally perceived wellbeing most often reflects not only subjective, but also objective factors. Climate change, effects by environment can be understood

as objective factors of person wellbeing. On the other hand, this wellbeing interface with climate change becomes an object of human feelings and worries when it reflects particular positive or negative personal experiences.

2. The interface between human wellbeing, subjective health and climate change following territorial dimension is little studied, so this becomes an opportunity to learn more about these phenomena by focusing on a territorial approach and other human related factors.
3. Research results disclosed that perception of wellbeing (happiness and satisfaction with life) and its evaluations in relation to climate change were mostly positive in ESS Round 8 (more than 5 scores) and vary on average between 7 and 9 scores, while correlation between wellbeing and climate change variables is very weak. The links between wellbeing and health were significant for respondents, regardless of where the respondents lived, but the aspects of health and wellbeing are still largely missing in big international research or assessed inconsistently as observed in the ESS case – this is the limitation of possibility to make comparison following time dimension. It was found that around 80 percent of respondents explored that their wellbeing is linked to a positive attitude towards nature and environment. These data showed that while respondents tend to care about the environment, it still seems difficult to link environmental change and its possible impact on climate change. This is largely due to the need to raise human environmental awareness.
4. As wellbeing is more than just personal happiness or satisfaction with life, so wellbeing research at individual level touching the attitudes of the population itself towards both environmental change in general and climate change are still too little studied. This implies that interface between wellbeing and environmentally friendly beliefs and solutions have to be the object not only in science level, but policy level as well.

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SOME ASPECTS ON MAPPING TECHNOLOGIES USED FOR CAPTURING AND MODELLING OF SMALL ARCHITECTURAL OBJECTS

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Abstract

The mapping of protected architectural heritage objects acquiring valuable geoinformation data is relevant today and in the future. The research is based on detection the preferable mapping technique for inspection and capturing the position of small architectural objects in public space, presenting the real geographic/ cartographic information for consumers in appropriate digital environment. The analysis and discussion involve the definition of appropriate technology, implementing goals of the culture strategy in Lithuania, preserving and updating information about cultural monuments, creating the open access to everyone.

Applying different techniques, two projects were realized: 1) the mapping and 3D modelling of sculptures in public space – small objects of city park; 2) the mapping of architectural heritage object – field museum, located in open territory with natural topography. Up-to-date mapping/ surveying methodologies as Remote Sensing (RS), Aerial Photogrammetry, Terrestrial Lidar Scanning (TLS), specialized geoinformation systems, UAV-Photogrammetry and classical surveying have been used for providing the spatial products of area topography and 3D models of any architectural objects, opening up cultural values of protected unique objects for the public and allows them to be easily accessed remotely.

The analysis of results deals with applicability of TLS technique, that provides effectiveness of 3D modelling and UAV-Photogrammetry with high resolution of aerial imaging and modelling solution. Some disadvantages have been highlighted on the use of orthophoto map for Geographic Information Systems (GIS) needs.

Key words: 3D modelling technologies, small architectural objects, terrestrial laser scanning, UAV-photogrammetry, data processing, orthophoto map.

Introduction

The mapping of protected cultural heritage objects is relevant today and in the future. The idea is to commemorate cultural heritage objects, protecting them from degradation, to ensure the preservation of information, to increase the relevance and visibility, and to realize more convenient access to obtain GIS and geoinformation data.

Various institutions are involved with the common goal of promoting cultural heritage to Lithuanian and foreign residents by using information technologies. The digital maps are becoming public and accessible at the website to anyone who is interested.

Terrestrial Laser Scanning (TLS) refers to terrestrial Light Detection and Ranging (LiDAR) technology that captures XYZ coordinates of numerous points on surfaces by emitting laser pulses at those points and measuring the distance from the device to the target. Due to the large amount of data stored in a TLS point cloud, software packages are typically required to manage and analyze the data. A point cloud can be converted into a grid Digital Elevation Model (DEM) to facilitate topographic mapping and spatial analysis. TLS instruments are commonly divided into three categories based on the distance the laser light can travel to record a point in a field-of-view: short, medium and long-range scanners. A potential limitation to TLS approaches is the weight of the instrument (>20 kg including the battery) (Vosselman & Maas, 2010; Terrestrial Laser Scanning, 2020).

Unmanned Aerial Vehicle (UAV) is the platform that flies at low altitude and the integrated camera can successfully capture the images of different territories/ surfaces. UAVs of different models, classification and categories can be used for aerial mapping. The methodology of UAV photogrammetry is related to image data acquisition, processing and generation of aerial image products used in cartography, surveying or GIS. UAV photogrammetry is rapidly changing the classical methods of geodesy. A UAV with a mounted camera flying at low altitude above the ground has advantages especially in capturing images of linear objects and cultural monuments. It is possible to capture images when flying over different, dangerous areas: hilly areas, tidal or volcanic areas, earthquake areas, etc. (Černiauskas & Bručas, 2014; Haala *et al.*, 2011; Ruzgienė, Berteška *et al.*, 2015).

Nowadays, aerial surveying is one of the most popular methods to collect 3D information about the surface and other objects with the help of high-resolution images. The quality of the images and aerial survey products mainly depends on the successful performance of the aerial mission, the qualified management of the photogrammetric workflow, and the appropriate development of the aerial survey requirements. The UAV mission must be conducted in good meteorological conditions - light wind (1.6–3.3 m s⁻¹) and minimal cloud cover (Ruzgienė *et al.*, 2017; Eisenbeiss, 2009; Neitzel *et al.*, 2011; Linder, 2009).

The goal of research is to describe the preferable mapping technique for inspection and capturing the position of small architectural objects in public space, presenting the real geographic/ cartographic information for consumers in appropriate digital environment.

Materials and Methods

The goal of the research is to find out an effective technology for mapping, visualization and inspection of small objects of cultural/architectural heritage, such as sculptures, located in regional parks. The goal of the cultural strategy in Lithuania is to preserve and update the cultural objects that unite European cultural values, ensure their continuity, create open access and competitiveness in contemporary cultural diversity. Current mapping/surveying methods such as Remote Sensing (RS), aerial cartography with the use of UAV photogrammetry, TLS and GIS provide the spatial products of area topography and 3D models of any architectural objects, which open up cultural values of protected unique objects to the public and enable easy remote access.

The new Leica Nova MS60 MultiStation enables single-device surveying, combining high-speed 3D laser scanning capabilities, GNSS connectivity and digital imaging. Features of the MS60 include a high laser speed of up to 30,000 points per second, optimized scan area definitions, customized scan management and an improved scan path for zenith scans. Measurement professionals can make decisions and perform point cloud analysis, such as flatness analysis, directly in the field. With the Nova MS60 scan data, point positions in the field can be displayed graphically and in real time (GPS World, 2020).

Laser Scanner Stonex X300 made in Italy is a 3D scanner designed to deliver effective results every day and on every project. X300 has its own line of accessories to work better, it can control smartphone or tablet, allows it to work where others fail, regardless of dust, humidity, heat or shocks (Stonex, 2020).

3Dreshaper is a scanner software for surveyors and can perform point cloud processing (manual and automatic filters, merging, colour), 3D meshes (smoothing, filling holes, enhancing edges), 3D inspection of data, polylines, CAD surfaces, calculating Digital Surface Model, longitudinal profiles, classifying points, etc. JRC 3D Reconstructor is the cross-platform, powerful software to manage LiDAR point clouds: import, process and manage data from terrestrial, handheld, mobile and airborne laser scanners and easily integrate UAV and 3D image data in a single platform (Reshapter 3D; JRC 3D Reconstructor, 2020).

The use of Unmanned Aerial Vehicle (UAV) with integrated technical means (cameras, laser scanners,

GPNS) for mapping various objects leads to a new standard of surveying technology. The standard technical means of Dà-Jiāng Innovations (DJI), China, used for surface mapping: the unmanned aerial vehicle MATRICE 600 PRO with the possibility of integrating the Zenmuse X5 camera, the ZENMUSE XT thermal camera, the MAPPER LITE 2 laser scanner, GPNS, etc. The MATRICE 600 PRO can work all day long and work efficiently for those who require the product of high accuracy. The integrated UAV camera is equipped with an image sensor that captures very sharp and colorful images. For UAV launching, the risk elements should be clarified, such as obstacles, wind speed (Dji Enterprise, 2020).

Pix4Dmapper, an image processing software developed in Switzerland, is the main tool for applying advanced technologies in UAV deployment. The software comes with computer vision algorithms combined with photogrammetric techniques to produce products with the highest accuracy and with minimal manual interaction. Pix4Dmapper software provides efficient capabilities for generating orthophotos, surface modelling, etc. Workflows with this package are fully automated and flexible, data input is scalable, output data is easily editable and on-site quality assessment is instantaneous (Pix4D, 2020).

By using different technologies, platforms and sensors to collect point data and images, the main processing procedures remain as follows: Aerial triangulation, image orientation, point cloud generation for surface modelling, orthophoto map generation, and vector data acquisition for GIS or cartographic needs. The relationship between images and object coordinates can be established when the coordinates of ground control points are determined using classical surveying technologies that measure with global positioning systems (GPS) or total stations (McGlone, 2004; Rock *et al.*, 2011; Nurminen *et al.*, 2013).

In order to describe some aspects of mapping technologies getting the real time information about sculptures and topography, defining the best solution for selection of appropriate mapping technique, the GIS and photogrammetric workflow was developed as follows:

- Realization of two projects:
 1. The mapping of sculptures in public space – small objects of the city park;
 2. The mapping of architectural heritage object – the field museum, located in open not densely dwelled territory with natural topography.
- First project:
 - Scanning of sculptures by the use of terrestrial laser scanner (TLS technology) and taking photography by the camera;
 - 3D modelling of sculptures surfaces by the special software – *3D Reshaper*;

- Construction of the thematic map using GIS techniques (*ArcGIS*) – overlaying positions of sculptures on the orthophoto map and showing the routs for public needs.
- Second project:
 - UAV flight to capture images with the high resolution camera.
 - Simultaneous scanning of the surface using LiDAR during the UAV flight.
 - Image data processing: generation of point cloud, 3D model and orthophoto.
 - Surface modelling from LiDAR data.
- Analysis and evaluation of the results of the project realisation.

Results and Discussion

During experimental investigations two projects have been realized with different objectives (technologies), area features, objects and topography: 1) mapping of sculptures – small objects located in the city park/ public space; 2) mapping of architectural heritage object – the field museum, located in open territory with natural topography.

First project. Study area – the sculptures park located in Klaipeda city, Lithuania is the open-air art gallery with 116 works of art of various thematic and 6 historical objects, situated on an area of 10 ha (Figure 1). This object was selected because of great significance as nature and art monument combining historical memorial legacy, modern decorative sculptures and the use of public space for cultural events. The mapping of sculpture park objects is important activity for obtaining information that can be used for construction a modern data base, disseminating for everyone’s needs by the use of smart devices (Mažosios Lietuvos, 2020).

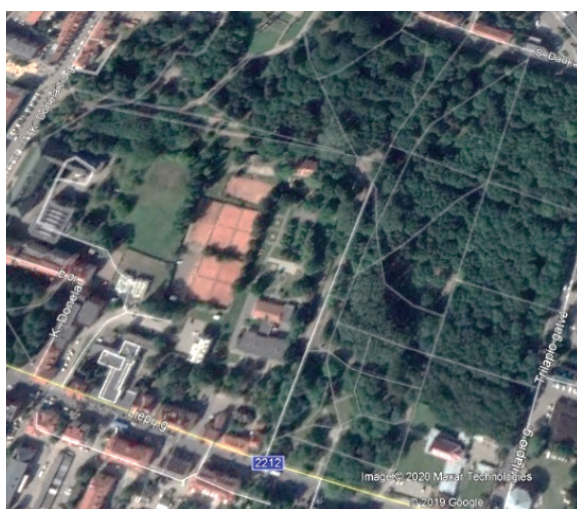


Figure 1. Study area: general view and fragment of sculptures park in Klaipeda city from *Google Earth* application.

Data acquisition and processing. 116 sculptures and 6 historical objects were scanned by the use of TLS with laser scanner *Leica Nova MS60*.

The photographs of all sculptures by the use of high-resolution camera were gained from four stations (at the sides, front, rear of the sculpture) and sometimes from additional stations depending on the complexity of the sculpture. These photographs were used for 3D modelling.

Software *3D Reshaper* has been applied for 3D modelling of all sculptures in a virtual environment. The virtual geoinformation data can be found at the platforms of www.regia.lt or www.mlim.lt and can be used by everyone. 3D modelling was performed step by step: importation of points cloud gained from laser scanning of sculptures; TIN creation, filling of gaps; creating of real image; shading of invisible areas, generation of three-dimension model.

The example of 3D modelled sculpture named “Bangpūtys” by software *3D Reshaper* is presented in Figures 2, 3 and 4.

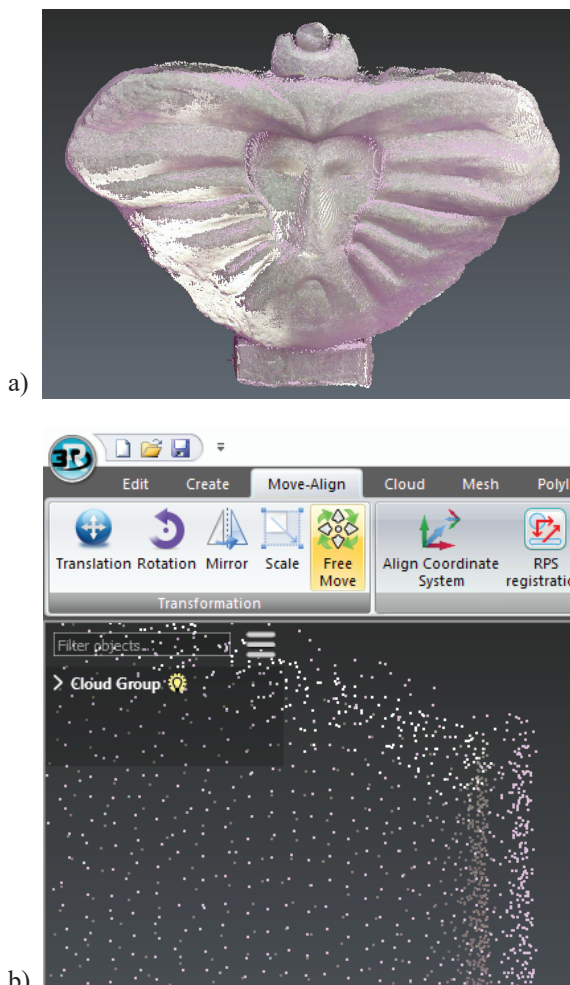


Figure 2. a) View of sculpture named “Bangpūtys”
b) Point cloud imported in *3D Reshaper* software.

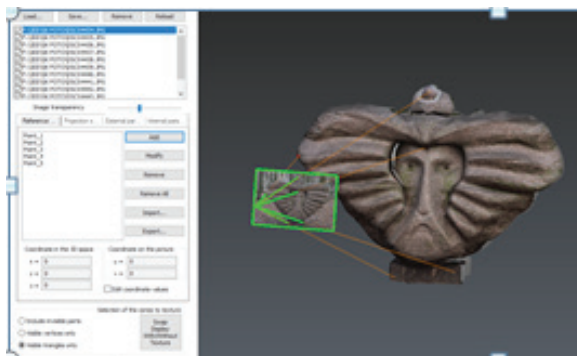


Figure 3. Extraction of a real image model: orientation of sculpture model, used 4 photographs.



Figure 4. 3D model of sculpture „Bangpūtys“ generated from TLS data.

Thematic map construction. The spatial data set was created with software application *ArcGIS*. The orthophoto map of study area and topographic survey with sculptures planimetric coordinates were provided by Klaipeda city municipality. These data were imported in *ArcGIS* overlaying positions of sculptures onto the orthophoto map (Figure 5).



Figure 5. Sculptures position onto orthophoto map.

Figure 6 shows the constructed map of sculpture park with small objects and the routes for public needs.



Figure 6. The map of sculpture park constructed with GIS technology: software application *ArcGIS*.

Second project. Study area – architectural heritage objects Baubliai, located in Dionizo Poskos antiquities field museum, Bijotų village, Lithuania (Figure 7). Oaks that were about a thousand years old, are called Baubliai. The museum shed oak stalk with straw roof, coated by ribbons, cementitious foundations – the writer and historian, enlightener of culture D. Poška rested and worked at the end of XIX century. Baubliai, has been declared as a significant historical, cultural, ancient monument of Lithuanian culture with no analogue. Nowadays Baubliai (Baubles) are proofed by glass covers (Baubli museum, 2020).



Figure 7. Study area: the locality of field museum with cultural monuments Baubliai, Bijotų village.

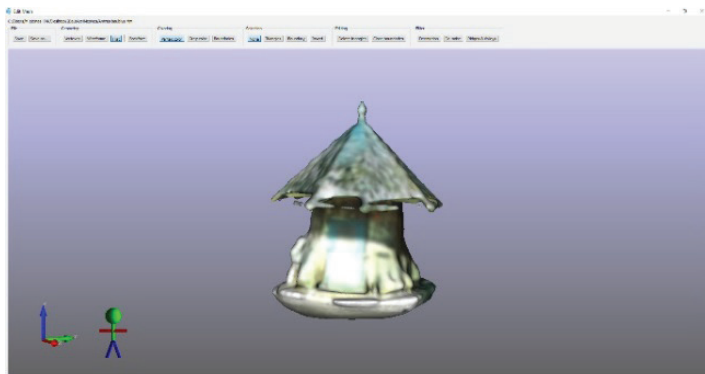


Figure 8. Generated 3D model by the use of TLS technology.



Figure 9. UAV flight routes executed over territory of museum: mission hub – *Litchi* for DJI Mavic, version 2.9.1.

Measurements and mapping procedures. Two Baubles were scanned with laser scanner *Stonex X300* – used TLS technology. Because both Baubles were under a closed glass and enclosure with a roof, the scanning procedure becomes complicated. For both Baubles, due to the trapezoidal roof, it was decided to measure from six different positions outside and also inside with scanning angle 75–90 angles. Measuring conditions were made more difficult because of the tapering roof; therefore, the laser scanner had to be raised higher. Due to the difficult measurement conditions mentioned above, the measurements took five hours. 3D modelling of Baubles was performed with software *JRC 3D Reconstructor* processing, unifying, correcting of the point cloud. Generated 3D model of one Bauble is presented in Figure 8.

UAV photogrammetry technology was used for experimental measurements. The low-cost and lightweight drone, model *MATRICE 600 PRO*, DJI with mounted gimbal camera *Zenmuse X5* (sensor size – 17.3×13.0 mm, resolution – 4608×3456 px., focal length – 15 mm) was used for photogrammetric data acquisition. Before taking the images, a photogrammetric network was created – 8 ground control points (GCPs) were well distributed and marked on the terrain. The coordinates of the targets were determined by GPS in the LKS94 coordinate system using the LitPOS network. The planning of the UAV flight over the experimental area was performed using *Litchi* hub software. Figure 9 shows the flight routes over the Baubles Museum area. The flight lasted about 20 minutes.

Digital photogrammetric software *Pix4Dmapper* was used for images processing, exterior orientation, generation an orthophoto map and 3D models (Figure 10). Data set consists of 396 images, georeferencing

of images was obtained with accuracy of mean RMS error – 1.0 cm.



Figure 10. Aerial mapping products of museum territory: orthophoto map and DSM.

Verified survey information and survey area results include the application of various technologies to map, visualize, and inspect small cultural/architectural heritage properties. The analysis and

discussion involve the definition of appropriate technology, implementing goals of the culture strategy in Lithuania, preserving and updating information about cultural monuments, creating the open access to everyone.

Main features of study areas and objects are: for the first project – sculptures, located in the city park, in public space with natural topography; for the next project – field museum, two heritage objects Baubles, located in open territory.

In the first project – 3D modeling of architectural small objects and opening the way for public remote accessibility using the created map – have been used up-to-date mapping/ geoinformation technologies as follows:

- RS – the use imagery from satellites in *Google Earth* (simultaneously *Street View*) application for overview general situation of study object (Figure 1).
- TLS – scanning sculptures with the Leica Nova MS60 MultiStation laser scanner, 3D modeling through the use of 3D Reshaper software. The MS60 speeds up workflows by combining technologies (imaging, scanning capabilities and GNSS connectivity) in this all-in-one device. With the 3D Reshaper software, all measurement and scan data can be visualized in a 3D environment to perform quality and completeness corrections. The results of the applied TLS technology are shown in Figures 2, 3 and 4 (from a sculpture).
- Geoinformation Systems – the use of software application *ArcGIS* for thematic map construction, getting the topographic survey and coordinates from other data sources – city municipality.
- Aerial Photogrammetry – the use of orthophoto map with resolution of 10 cm for presentation of sculptures positions and routs in the city park for public needs (Figure 6).

In the second project – 3D modelling and mapping of open territory with the field museum and Baubles – have been used such technologies:

- TLS – scanning Baubles with laser scanner *Stonex X300*, 3D modelling with software *Stonex Reconstructor*. Advanced scanner *Stonex X300* allows quickly to collect multiple scans, software *Reconstructor* is powerful for 3D laser scanner data processing. Figure 8 shows the generated 3D model by the use of TLS technology.
- Classical surveying – photogrammetric network creation (reference base with 8 ground control points) measuring by GPS or total stations.
- UAV photogrammetry – aerial photography with UAV system (MATRICE 600 PRO, camera Zenmuse X5), photogrammetric data processing

using Pix4Dmapper software. The results of image processing are: average Ground Sampling Distance (GSD) – 2 cm, dataset with 396 images, camera optimization – 3.2% relative differences between initial camera parameters (below 5%), matching points per image – 22065, georeferencing accuracy - the average RMS error of 8 GCPs (3D) measurement is 0.010 m (is below 3×GSD), the overlap of images are: forward – 85% and lateral – 70%. Aerial image products of the museum site: Orthophoto map and DSM (Digital Situation (or Surface) model) (Figure 4). The following rule (criteria) can be applied for accuracy assessment of aerial image products: Errors of planimetric coordinates should be higher than 1.6×GSD; heights – 2.5×GSD.

Conclusions

Research is based on defining the expedience of application of different technologies for mapping of small cultural heritage objects and their environment with different topography.

The technology of TLS was employed in two projects, using different types of laser scanners and software for 3D modelling. Comparing actions of laser scanners *Leica Nova MS60* and *Stonex X300* at the experimental site: these instruments were the best available solution for 3D scanning, balancing efficiency and accurate outputs, showing the scan data at the same day when it is collected. In the case when a scanned object is closed under the glass and enclosure with a roof (Baubles in the field museum), the scanning procedures became unusual (discovering station position and scanning angle). 3D laser scanner data processing with software *Stonex Reconstructor* is appreciated, effective and flexible.

The technology of UAV photogrammetry (MATRICE 600 PRO, Zenmuse X5, Pix4Dmapper) used in the experiment shows that such a solution for aerial photography and 3D modelling is successfully applicable guaranteeing high visuality of the results.

The technology of Aerial Photogrammetry is not applicable for GIS data presentation (positions of sculptures and routs for public needs) onto orthophoto map. The experimental site (the city park) is densely covered with vegetation (trees, etc.); therefore, the surface is not seen on the orthophoto map (see Figures 5, 6). Due to different data sets accuracy, the two data bases – the orthophoto map and topographic survey are not possible to superimpose. In this case, constructing a digital map with the help of the GIS technologies, the use of aerial mapping products from UAV-Photogrammetry technology is highly recommended.

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ANALYSIS ON THE OPTIMALITY OF LITHUANIAN LANDSCAPE STRUCTURE

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Abstract

The aim of this study was to perform an analysis of the optimality of the landscape structure of the Republic of Lithuania.

Various scientific methods were used in the study, namely: comparative, grouping, analytical, statistical data, graphical representation analysis. After calculating the formulas, the ratio of relatively natural and cultivated land in Lithuania and counties was determined, the relative deviation of the landscape structure from the optimal value of the ratio was estimated and the optimality class was determined.

The article presents an analysis of the changes in the natural, anthropogenized and anthropogenic landscape of the Republic of Lithuania during the time period between the years 2002 and 2020. It was found that in the analyzed period the area of natural landscape increased by 4.63%, that of anthropogenic – increased by 7.08%, that of anthropogenized – decreased by 36.34%. Assessing the structure of the country's landscape, it can be seen that in 2020 the largest part of the country's landscape was occupied by anthropogenized landscape (55.79%), the smallest – by anthropogenic landscape (5.65%), and the natural landscape accounted for 38.56% of Lithuania's territory.

Calculations were also performed, which established that the ratio of relatively natural land and cultivated land in Lithuania $R_{ns} = 1.43$. After estimating the relative deviation of the Republic of Lithuania from the optimal ratio value (D_r), it was obtained that $D_r = -1.14$, which means that the country's optimality class is B1.

Key words: landscape, components, optimal landscape, landscape structure.

Introduction

U. Walz (2011) describes the structure of a landscape as composition and arrangement, and the resulting spatial relationships between its individual elements can be described and quantified by means of landscape metrics.

R.H. Haines-Young (2009) notes that landscape structure means the pattern of a landscape, which is determined by its type of use, but also by its structure, for example, the size, shape, arrangement and distribution of individual landscape elements. For the delineation of these landscape elements, or so-called *patches*, often land use or land cover units are used. In this context, *land cover* refers to the physical surface characteristics of land (the vegetation found there or the presence of built structures), while *land use* describes the economic and social functions of that land.

Landscape is composed of a combination and mixture of disparate elements, habitats or land cover classes (Turner, Gardner, & O'Neill, 2003).

Landscape image comprises its spatial and structural parts, the formal visual and cultural aesthetic expression of the landscape. In accordance with this holistic image of the landscape, the manifestation of these special elements and visual functions is reflective of the natural and cultural coherence and beauty of long functioning natural and cultivated landscape systems (Krause, 2001).

The structure of near-natural landscapes may be referred to as *primary landscape structure*. Man intervenes more or less directly in biodiversity through

land use. So, landscape structure resulting from anthropogenic uses can be referred to as *secondary landscape structure* (Walz & Syrbe, 2013).

Landscape pattern is more fragmented around city centres and along coastlines, where urbanization and human economic activities are more concentrated (Uemaa *et al.*, 2009).

R. Skorupskas and P. Kavaliauskas (2007) state that an integral, ecological approach combined with bio-psycho-socio-ecological and ergo-economical requirements to the environment currently becomes the main necessity of landscape optimization. An optimal landscape is instable in time. This is due to many factors, for example, ergo-economic suitability, geoeological determinativeness, social conventionality and perceptual comfortness. In the science article, the authors state that a set of anthropo-ecological criteria determines different interpretations or of the optimal horizontal structure of landscape: ecological, ergo-economical, socioecological perceptual.

Landscape structure reflects the results of policies and practices, and is well-suited as a target for management actions (Dramstad *et al.*, 2001).

The object of article is the optimality of the Lithuanian landscape structure.

The aim is to perform an analysis of the optimality of the landscape structure of the Republic of Lithuania.

Tasks to be resolved:

1. To analyze the change of Lithuania's natural, anthropogenic and anthropogenized landscape in 2002–2020.

2. To calculate the ratio of relatively natural and cultivated land in Lithuania (R_{ns}).
3. To evaluate the optimality of the landscape of the Republic of Lithuania and counties as well as its classes.

Materials and Methods

First of all, during the research of determining the optimality of the Lithuanian landscape structure, the analysis of the articles published in scientific publications on the examined topic was performed.

The article presents a comparative analysis of the change in the area of the natural, anthropogenized and anthropogenic landscape in 2002–2020.

Using the grouping method, the components belonging to the natural, anthropogenized and anthropogenic landscape are divided. The change in the areas of the analyzed landscape components was also examined. The data of the Land Fund of the Republic of Lithuania for 2002–2020 were used for the analysis. The percentage and hectare distribution of the country's landscape types in 2020 was estimated.

The analysis of the ratio of relatively natural and cultivated land in Lithuania was performed and the R_{ns} of the country and ten counties were calculated. The county data were compared and the county with the most optimal ratio of relatively natural and cultivated land was determined.

The relative deviation of the landscape structure of the Republic of Lithuania and counties from the optimal ratio value (D_p) was also calculated and the optimality class was estimated based on the table *Determination of the territory optimality class according to the distance of its natural and artificial land use from the optimal value*.

Thus, in writing the article, not only the above-mentioned methods were used, but also the methods of analytical and logical analysis. The article presents graphic representation methods (6 figures in total). Figures 5 and 6 were made using ArcGIS program.

Results and Discussion

Lithuanian natural landscape

A landscape covers all of the territory of the country including cities, towns, rural areas, forests and waters; it greatly influences the life and activities of society; it is the foundation of national identity and part of quality of life (Čiegis & Burgis, 2012).

The structure of the Lithuanian landscape, formed and shaped by natural and anthropogenic factors, is diverse and multi-layered.

Forests, water bodies and wetlands are components that make up the natural landscape.

The tendencies of changing the naturalness of the landscape are to some extent expressed by the development of the country's forest cover. In

Lithuania, forest area covers 2,156,033.39 ha or 33.02%. Comparing 2002 with 2020, the forest area in Lithuania increased by 159,154.22 ha, i.e. 7.97%.

The forest area has developed due to participation in the Rural Development Program, the enforcement of the forest development program, etc.

Another component of the natural landscape is water bodies. In 2020, water bodies in the country occupied 266,532.84 ha and accounted for 4.08% of the territory of Lithuania. After the analysis of the change of water bodies in 2002–2020, it was established that their area increased by 4,368.39 ha or 1.67%.

Wetlands are one of the most natural components of the natural landscape. It is one of the most important parts not only of the natural landscape, but also of the whole Lithuanian landscape, these are territories of special ecological and aesthetic significance. Unfortunately, this natural component is the most ignored and endangered.

Wetlands in Lithuania in 2002 occupied 147,078.84 ha, in 2020 – 94,871.10 ha, which means that in 2002–2020 the area of wetlands decreased by as much as 52,207.74 ha or 35.50%.

The wetland area was shrinking due to human activities, climate change and natural processes.

The analysis of the components of the relatively natural landscape shows that the area of forests and water bodies increased between 2002 and 2020, but unfortunately the area of wetlands decreased.

Examining the change of the natural landscape, it was found that the area increased by 111,314.87 ha or 4.63% during the analyzed period (Figure 1).

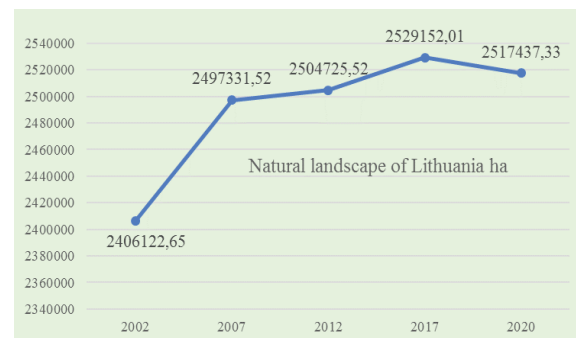


Figure 1. Natural landscape area change in hectares in Lithuania 2002–2020.

The natural landscape area has increased due to the development of forests and water bodies.

Anthropogenized landscape

The following components can be included in the anthropogenized landscape: agricultural land (arable land, orchards as well as meadows and natural pastures), tree and shrub plantations, unused land.

The area of agricultural land in Lithuania decreased by 88,053.11 ha or 2.53% in 2002–2020.

Human economic activity influences the change of land use, as the composition of land use changes with the change of purpose.

Greenery of trees and shrubs in the analyzed period increased as much as 117,643.34 ha or 138.91%. The reason for the increase of this land use is the development of green areas and the implementation of afforestation programs.

In 2002–2020, the areas of unused land in Lithuania decreased by 166,692.67 ha or 80.36%.

The analysis of the change in the areas of the components of the anthropogenized landscape shows that in the Republic of Lithuania in 2002–2020 the areas of agricultural land and unused land decreased, and the areas occupied by trees and shrubs increased.

Between 2002 and 2020, the area of the anthropogenized landscape decreased by 137,102.44 ha or 36.34%. (Figure 2).

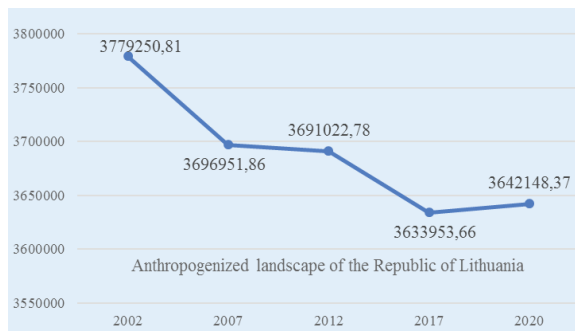


Figure 2. Anthropogenized landscape change in Lithuania in hectares during the period between the years 2002 and 2020.

The reason for the decrease in the area of anthropogenized landscape is the decrease in the area of agricultural land (2.53%) and unused land (80.36%).

Anthropogenic landscape.

Anthropogenic landscape includes: built-up areas, roads and damaged land.

Urbanization as a process is characterized by many factors or measurable variables, such as urban development, population growth in urban areas, consolidation of the urban network, or other socio-demographic shifts in society (Sillence, 2007).

In the period of 2002–2020, the area of built-up territories in Lithuania increased by 51,373.81 ha or 27.32%, and in 2020 it occupied 239,421.21 ha.

Based on the data of the Land Fund of the Republic of Lithuania (Nacionalinė, 2002–2020), it was established that in 2002–2020 the road area in the country decreased by 26,199.14 ha or 19.91%. In 2020, the road area covered 105,401.82 ha.

It can be said that this decrease in road area is conditional, because until 2007 the data of theoretical calculations of road area were provided, which were

inaccurate, and in the following years cadastral measurements were started, during which data on road area are constantly updated every year. At present, more than 50% of cadastral measurements of road areas have been performed in Lithuania.

In 2002–2020, the area of damaged land in the Republic of Lithuania decreased by 762.12 ha or 3.05%.

The area of damaged land decreased due to the closure of non-compliant landfills and the disposal of illegal landfills, as well as the reclamation of quarries.

After analyzing the change in the area of the Lithuanian anthropogenic landscape in 2002–2020, it was established that the above area increased by 24,412.55 ha or 7.08%. (Figure 3).

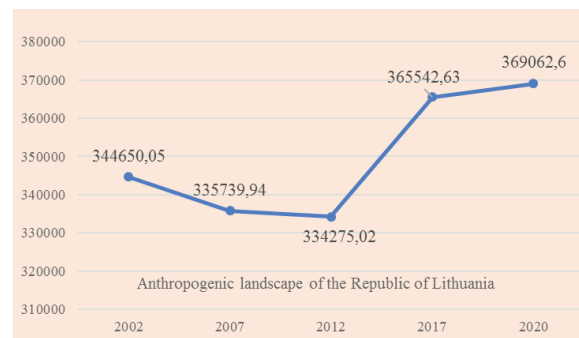


Figure 3. Anthropogenic landscape change in Lithuania in hectares during the period between the years 2002 and 2020.

The reason for the increase in the area of anthropogenic landscape is the development of built-up areas (27.32%).

After the analysis of the landscape of the Republic of Lithuania, it was established that in 2020 the anthropogenized landscape occupied the largest part of the country’s landscape (55.79% or 3,642,148.37 ha), the smallest part of the landscape was occupied by anthropogenic one (5.65% or 369,062.60 ha). The natural landscape in Lithuania occupied 2,517,437.33 ha and accounted for 38.56% of the country’s territory (Figure 4).

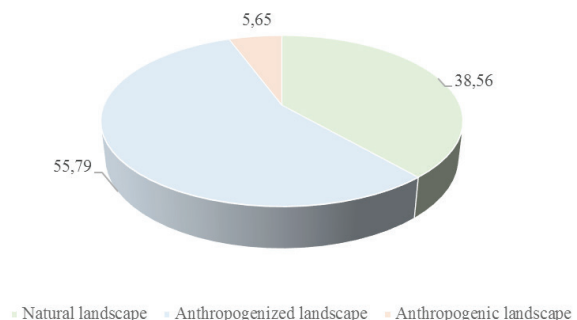


Figure 4. Distribution of Lithuania landscape in 2020, in percent.

Analysis of the ratio of relatively natural and cultivated land in Lithuania

The methodology of landscape formation (landscape benchmarks to be achieved) (Kavaliauskas *et al.*, 2013) states that the optimal landscape structure of a country is assessed on the basis of geoeological compensation index, when the active part of anthropogenic (anthropogenized) land occupies 38%, passive part or natural (relatively natural) land occupies 625 (Skorupskas & Kavaliauskas, 2007).

Thus, the landscape cannot be considered optimal if the minimum percentage of natural areas required to compensate for anthropogenic impacts is not reached.

From the above analysis and Figure 4 it can be seen that in 2020, the natural areas of the Republic of Lithuania occupied 38.56%, while the anthropogenic together with the anthropogenized landscape accounted for 61.44%.

Taking into account the diversity of land uses, it is possible to calculate the ratio of relatively natural and cultivated land (R_{ns}) for any sufficiently large (regional level) area with specific boundaries using the formula:

$$R_{ns} = \frac{P+M+0.5A+0.8V}{U+T+0.5A+0.2V} \quad (1)$$

where R_{ns} is the ratio of relatively natural land (fraction in the numerator) and relatively cultivated land (fraction in the denominator) of the land of the territory: P – wetlands; M – forests; A – agricultural land; U, T – urban and technological components; V – water bodies.

After performing the calculations according to the above formula, it was established that the ratio of relatively natural land and cultivated land (R_{ns}) of the Republic of Lithuania is equal to 1.43.

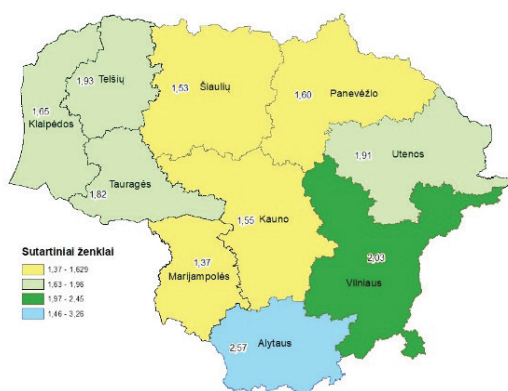


Figure 5. The ratio of relatively natural land and relatively cultivated land in the counties of the Republic of Lithuania.

The structure of the landscape is natural when $R_{ns} = R_o$. R_o is the optimal ratio value, which is equal to 1.63. There are ten counties in the territory of Lithuania.

After analyzing the ratio of relatively natural land and relatively cultivated land, it was found that the optimal ratio of relatively natural land and relatively cultivated land is in Klaipėda county ($R_{ns} = 1.65$) (Figure 5). It can be stated that the optimal ratio of the mentioned land use is also in Tauragė ($R_{ns} = 1.82$), Utena ($R_{ns} = 1.91$) and Telšiai ($R_{ns} = 1.93$) counties.

The optimality of the landscape structure of the territories can be assessed by the following formulas:

$$D_r = \frac{R_{ns}}{R_o}, \text{ when } R_{ns} > R_o \quad (2)$$

or

$$D_r = \frac{R_o}{R_{ns}}, \text{ when } R_{ns} > R_o \quad (3)$$

here D_r is the relative deviation from the optimal ratio value (R_o); R_{ns} - the ratio of relatively natural land and relatively cultivated land in the territory; R_o is the optimal value of the ratio.

After calculating D_r and based on Table 1, the landscape structure optimality class is determined.

Table 1

Determination of the site optimality class according to the deviation of its natural and artificial land use ratio from the optimal value (Lietuvos Respublikos aplinkos..., 2015)

Ratio of natural and cultivated land (R_{ns})	R_{ns} deviation from optimal value (sometimes) (D_r)	Optimality classes
>78,25	>48,00	A6
13,37...78,24	8,01...48,00	A5
3,27...13,36	2,01...8,00	A4
2,46...3,26	1,51...2,00	A3
1,97...2,45	1,21...1,50	A2
1,631...1,96	1,00...1,20	A1
1,629...1,36	-1,00...-1,20	B1
1,35...1,09	-1,21...-1,50	B2
1,08...0,82	-1,51...-2,00	B3
0,81...0,20	-2,01...-8,00	B4
0,19...0,03	-8,01...-48,00	B5
<0,03	<-48,00	B6

After performing the calculations, it was obtained that the relative deviation of the Republic of Lithuania from the optimal value of the ratio is equal to -1.14, i.e. the country's optimality class is B1, indicating that there are more cultivated lands than natural ones in the country's landscape. As mentioned above, the Lithuanian natural landscape makes up 38.56%.

After calculating the counties D_r and determining the optimality classes, it can be seen that the optimal structure – A1 class was determined in Klaipėda, Tauragė, Telšiai and Utena counties (Figure 6).

Class B1 is an almost optimal structure, with a small predominance of cultivated land. This class is established for the whole territory of the country and for Marijampolė, Kaunas, Panevėžys and Šiauliai counties.

Optimality class A2 was determined for Vilnius county, and A3 – for Alytus county. Classes A2 and A3 show that the above-mentioned county landscape is dominated by natural components.

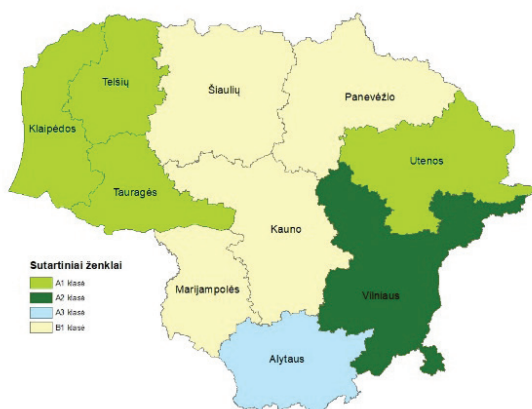


Figure 6. Optimality classes of landscape structure in counties of the Republic of Lithuania.

In 2020, the natural landscape in Alytus county occupied 55.85% of the county area, in Vilnius county – 48.08%. The value of the recommended indicator varies in individual regions of the country, which indicates the deviation of their geocological structure from the optimal proportion. Regional differences in the optimality of the landscape structure provide guidelines for increasing the optimality of the landscape structure, i.e. for optimization to A1 or B1 classes.

The landscape optimality structure must be formed taking into account the general optimality of the land use structure of the whole country, territorial structures provided for in the General Plan of the Republic of Lithuania (natural framework, protected areas, functional priority areas, presuming the respective land use structure, etc.), ecological compensation.

Conclusions

1. After the analysis of landscape change in the Republic of Lithuania during the period between the years 2002 and 2020, it was established that the area of natural landscape increased by 111,314.87 ha or 4.63%, the area of anthropogenic landscape increased by 24,412.55 ha or 7.08%, the area of anthropogenized landscape decreased by 137,102.44 ha or 36.34%.
2. In 2020, the largest part of the country's landscape made up anthropogenized landscape (55.79% or 3,642,148.37 ha), the smallest - anthropogenic (5.65% or 369,062.60 ha). The natural landscape covered 2,517,437.33 ha and accounted for 38.56% of the country's territory.
3. After calculating the ratio of relatively natural land and cultivated land (R_{ns}) in the Republic of Lithuania in 2020, it was established that it is equal to 1.43. Out of ten counties of the Republic of Lithuania, the most optimal ratio of relatively natural land and relatively cultivated land is in Klaipėda county ($R_{ns} = 1.65$).
4. The relative deviation of the Republic of Lithuania from the optimal ratio value (D_r) is equal to -1.14, which means that the country's optimality class is B1, which indicates that there are more cultivated lands in the country's landscape than natural ones. Class B1 was set for Marijampolė, Kaunas, Panevėžys and Šiauliai counties, A2 optimality class was set for Vilnius county, and A3 – for Alytus county. The optimal structure - A1 class – was determined in Klaipėda, Tauragė, Telšiai and Utena counties.

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CHANGES OF FOREST LAND COVER IN LITHUANIA DURING THE Period 1950-2017: A COMPARATIVE ANALYSIS

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Abstract

Due to human activities Lithuanian historical land use and land cover (LULC) changed. Forest land cover was also changing. 200 years ago, forests occupied almost 40% of the entire Lithuania territory, in 1914 – only 20%, and in 1939 – only 17%. The historical changes in forest land cover were mainly related to deforestation. Today, the forest cover is increasing in Lithuania, but changes within different municipalities boundaries differ. The aim of this study was to compare geodata of forest land cover, within different municipalities of Lithuania boundaries, in the 1950s and 2017 for a better understanding of spatial patterns of occurred forest land cover changes. To evaluate forest land cover changes in Lithuania, two geodatabases, representing the forest cover in the 1950s and 2017, were used. Methods of descriptive statistical analysis, spatial autocorrelation, cluster and outlier analysis using ArcGIS and MS EXCEL software were used to process, evaluate and represent the data of this study.

The results of this study revealed that forest land cover increased by 7.1% during the investigated period resulting in the forest land area proportion of 33.6% in 2017. Despite positive changes of Lithuania forest land cover, two municipalities met afforestation. Forest land covers most intensively, i. e. 17.1–31.1%, increased in the south-eastern part of Lithuania and west-central part of Lithuania. The most passive afforestation was detected in northern, central, and south-western parts of Lithuania, where forest land cover increased only from 1.2% to 4.9%.

Key words: forest land cover, forest land changes, spatial pattern.

Introduction

Human activity is a major force, which influences biodiversity as well as the climate of Earth through land use and land cover (Chaware *et al.*, 2021; Manzoor *et al.*, 2021). The primary mission of Earth was orientated on sustainable development of all life forms, but anthropogenic activities induced uncontrolled changes of steady processes and natural development. In 2012, the World Wildlife Fund (WWF) reported a study (Living, 2012) where it was stated that for the first time around 1980, the general needs of humanity exceeded the restorative power of the Earth. In 2008, humanity's global needs exceeded the Earth's restorative power by 30%. This means that humanity meets its needs today by consuming the capital of the planet, thus moving toward disaster when the capital is exhausted (Palaima & Mierauskas, 2013). Humanity needs more and more land to carry out its activities. Thus, forest lands were shifted to urban and agricultural surfaces (Ruseckas & Tiškutė-Memgaidienė, 2013; Tiškutė-Memgaidienė & Ruseckas, 2014). Deforestation and forest degradation, in turn, brought climate change (Agrawal *et al.*, 2011; Koh *et al.*, 2021). The most striking changes due to deforestation were monitored in South America and South-Eastern Asia during the last decades of the 20th century. On a small scale (in small countries), this process was also observed (DeFries *et al.*, 2007). It is good that the consciousness of humanity has increased and afforestation is a more common process in most countries, especially developed ones. Although forest land area increases, forest land spatial structure remains not optimal (Juknelienė *et al.*, 2017; Tiškutė-Memgaidienė, 2018). Thus, more studies investigating

changes in land covers both small and large scale and possible decisions for future generations are required.

As Lithuania is located in Central Europe in the transitional zone between the boreal coniferous and the nemoral broadleaved forests, Lithuania forests are categorized as the European hemi-boreal mixed broadleaved-coniferous forest type (Mozgeris *et al.*, 2019). It means that forests have been the most common land cover in the Lithuania landscape since ancient times. Many forests were cleared down during World War II to meet military needs. Therefore, in the post-war years, the expansion of forest cover and the increase of the growing stock productivity came into a focus. Moreover, due to global climate changes and after the ratification of the Kyoto Protocol, which deals with human efforts to mitigate environmental disturbance, afforestation became a more important field, and the particular decision was implemented in the Lithuanian legislation. In total, the afforestation in Lithuania is positive, but this process differs in particular territories (Tiškutė-Memgaidienė, 2018).

The aim of this study was to evaluate the spatial pattern of forest land cover, within municipalities of Lithuania boundaries in the 1950s and 2017, employing GIS overlay techniques. This study will contribute to a better understanding of forest land cover changes in Lithuania. Also, it will provide a reference value for future researches on the alteration of the forest land cover since World War II.

Materials and Methods

This study covers all forested area of Lithuania territory. Two geodatabases were used in order to execute a comparative analysis of forest land cover

changes in Lithuania during the period 1950–2017. First, the geodatabase representing the forest cover status in the 1950s was used as the starting point. This geodatabase was conducted using historical orthophoto maps based on aerial photography within the period just after World War II, georeferenced to the coordinate system of Lithuania (LKS94), and stored in vector-data (Mozgeris, 2012). Second, the geodatabase representing the forest cover status on Jan 1, 2017, available from the State Forest Service was used to estimate changes of forest land area over a half-century. This State Forest Cadastre geodatabase is the latest geodata version of Lithuania forest land cover available in open access. The aforementioned two geodatabases were compared using GIS overlay techniques.

The forest land area, as well as forest land changes within different municipalities of Lithuania boundaries, were estimated and plotted on choropleth maps. To better understand the spatial pattern of forest land cover peculiarities, cluster and outlier analysis was performed: Anselin Local Moran's I based on the "Inverse-distance" contiguity was applied to identify statistically significant hot spots, cold spots and spatial outliers in the mapped forest land values. Global Moran's I was enabled to assess the global spatial autocorrelation of forest land cover within municipalities of Lithuania boundaries.

Results and Discussions

The initial data of this study has shown that forest land covered 1709.0 thous. ha of Lithuania territory in

the 1950s. This means that forests covered less than a third, i. e. 26.5% of the whole Lithuania territory. However, by 2017 the area of forest land expanded to 33.6% to reach 2178.9 thous. ha (Figure 1). The total increase in forest land area during the investigated period was 7.1%.

The histogram showing the frequency of occurrence of forest land cover, within municipalities of Lithuania boundaries, in the 1950s, as well as in 2017, Figure 2. Most frequent values were discovered to vary from 13.3% to 33.3% (with an average 26.2% and median 24.5%) in 1950s. However, in 2017 most frequent values of forest land cover, within municipalities of Lithuania boundaries were larger and varied from 15.8% to 43.8% (with an average of 34.2% and a median of 33.3%).

Although forest land cover within different municipalities boundaries is distributed randomly, the presence of statistically significant spatial clusters of forest land cover was observed in the 1950s (Global Moran's Index -0.074 , z-score -0.283 , p-value 0.777) as well as in 2017 (Global Moran's Index -0.015 , z-score -0.009 , p-value 0.993) (Figure 3).

Three types of spatial autocorrelation were observed using the Moran's I Local Indicators of Spatial Autocorrelation statistics (High-High, Low-Low, and High-Low). Positive spatial autocorrelation, represented by High-High spatial pattern clusters, was found in the southern part of Lithuania (Druskininkai municipality and Varėna municipality) in both 1950s and 2017. Positive spatial autocorrelation, represented by Low-Low spatial pattern clusters,

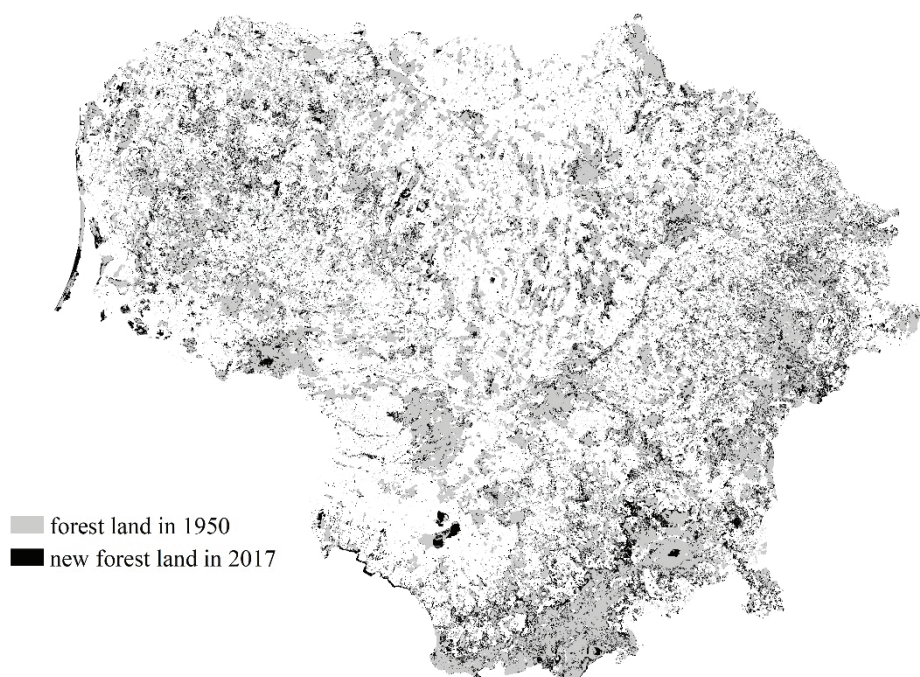


Figure 1. Lithuanian forest land cover in 1950s and 2017.

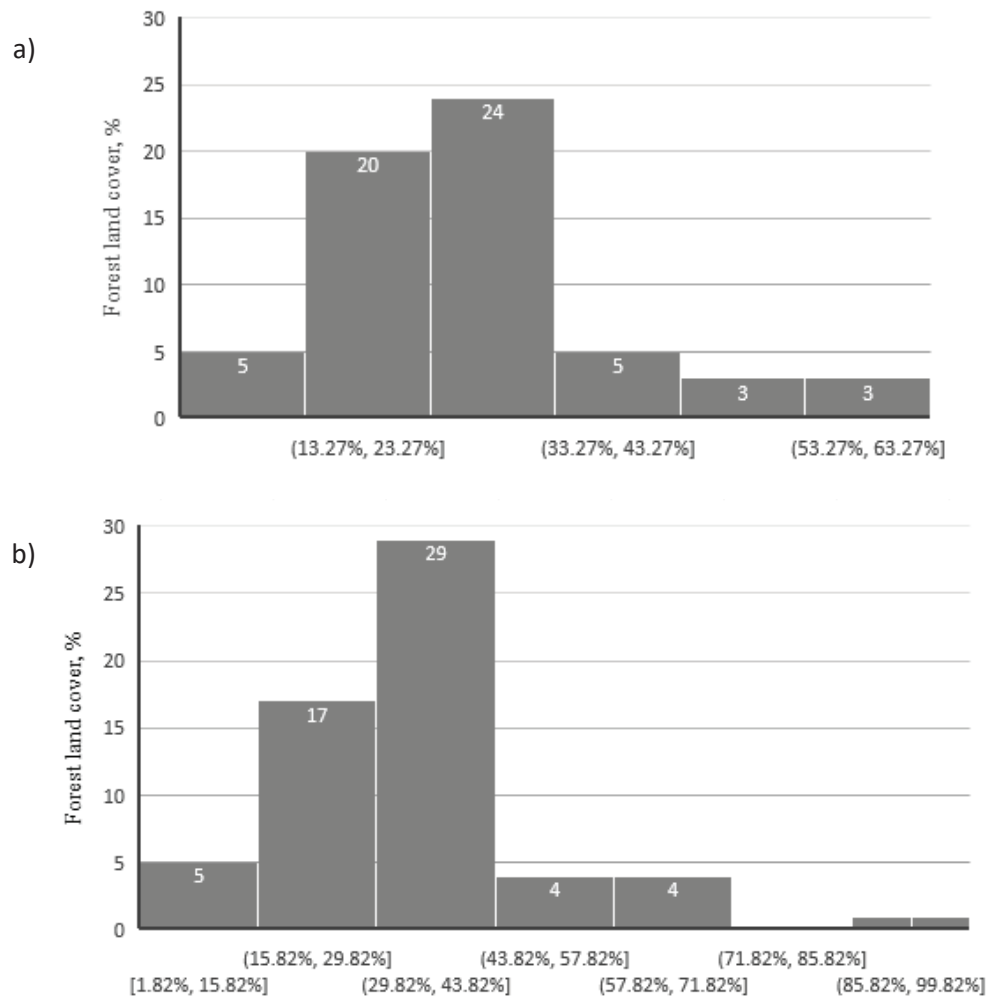


Figure 2. Histogram of forest land cover within municipalities of Lithuania boundaries in Lithuania: a) in 1950s; b) in 2017.

was mapped in the south-eastern part of Lithuania (Kalvarija municipality) in the 1950s, while in 2017, Low-Low spatial pattern clusters were observed not only in the south-eastern part of Lithuania (Kalvarija municipality) but also the northern part of Lithuania (Pakruojis municipality and Pasvalys municipality). This could be explained due to the inconsistent afforestation strategy of the Lithuanian government. Negative spatial autocorrelation represented by High-Low spatial pattern outliers was observed in the western part of Lithuania (Neringa municipality) and south-western part of Lithuania (Kazlų Rūda municipality) in both 1950s and 2017.

The modest value of forest land area in the 1950s was 3.3% (in Panevėžys city municipality), while in 2017, forest land area in this municipality was even lower; 1.8%, and Panevėžys city municipality was recognized as a municipality with modest forest land cover in whole Lithuania territory in 2017. This shows that even though forest land cover in Lithuania territory from the 1950s increased, some municipalities

experienced afforestation. Also, such changes could be explained by urbanization and changed habits of the Lithuanian population which led to an increase in population density in the biggest cities of Lithuania. Larger, but relatively small forest land cover in the 1950s was found in seven more municipalities: Šiauliai city municipality (4.9%), Kalvarija municipality (5.6%), Vilkaviškis municipality (7.3%), Pagėgiai municipality (13.2%), Marijampolė municipality (13.4%), Skuodas municipality (14.0%), and Pasvalys municipality (15.6%). As the results of this study have shown, the number of municipalities with low forest land cover in 2017 increased to 12 municipalities. The lowest forest land cover was found in same municipalities, monitored in the 1950s (Panevėžys city municipality (1.8%), Šiauliai city municipality (6.1%), Kalvarija municipality (14.9%), Vilkaviškis municipality (11.4%), Pagėgiai municipality (17.8%), Marijampolė municipality (16.6%), Skuodas municipality (20.7%), and Pasvalys municipality (17.3%)), also in four new municipalities: Kaunas city municipality (15.4%) and

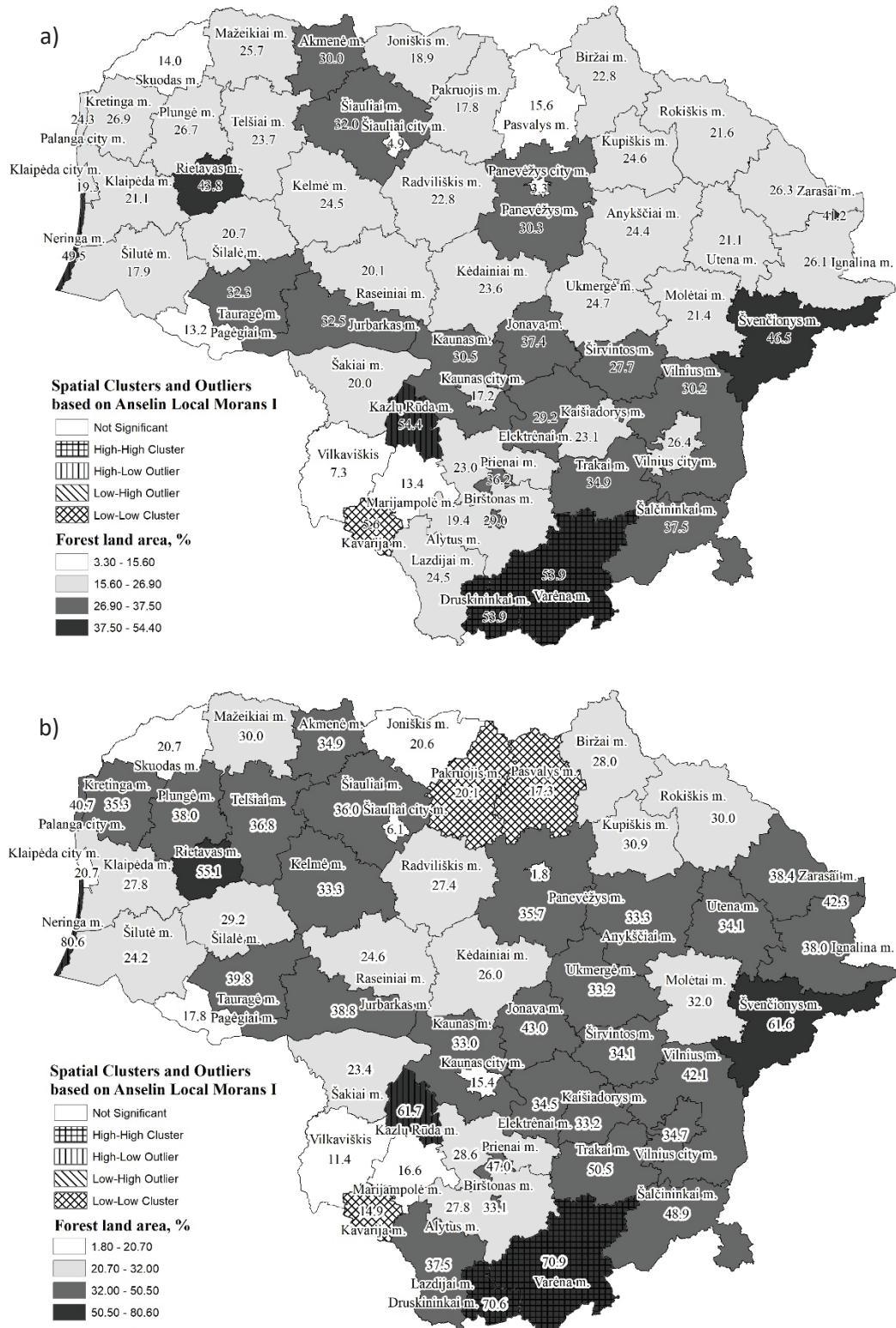


Figure 3. Spatial pattern of forest land within municipalities of Lithuania boundaries: a) in 1950s; b) in 2017.

Klaipėda city municipality (20.7%), also Pakruojis city municipality (20.1%) and Joniškis city municipality (20.6%). Excluding the largest Lithuania cities (Kaunas, Šiauliai, Panevėžys, Klaipėda), rural municipalities

with the lowest forest land cover geographically are located on the border of Lithuania territory.

The largest forest land cover in the 1950s was found in Kazlų Rūda municipality – 54.5%. The

- land cover were found not only in the south-eastern part of Lithuania but also in the northern part of Lithuania.
4. Two municipalities experienced afforestation during the investigated period. Changes in forest land cover were negative in Kaunas city municipality (-1.8%) and Panevėžys city municipality (-1.4%). Forest land covers most intensively, i. e. 17.1–31.1%, increased in the south-eastern part of Lithuania and west-central part of Lithuania. The most passive afforestation was found in northern, central, and south-western parts of Lithuania, where forest land cover increased only from 1.2% to 4.9%.

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PLANNING OF URBAN FORESTS IN RIGA AND MAJOR EUROPEAN CITIES

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Abstract

With the increase in the number of the global population, that is likely to grow also in the nearest decades, the expansion of cities continues at the expense of forests and farmlands, and in these new areas, a more significant role is granted to the interaction between cities and countryside, revealing diverse interests of stakeholders. It is necessary to preserve, and it is even desirable, to expand the green spaces of the urbanized territories. Vienna, Stockholm, Copenhagen and Riga were selected for the study. The authors looked at the experience of the urban and green area planning through the literature review of city planning documents. Analyses of results show that planning takes place at the city, suburban or regional level and in the case of Riga, its development is similar to the development of other large European cities. The share of the urban forests in the territory of Riga city and its suburbs is comparatively large. In the European cities, which are rich in forests, the territories of the urban forests are often owned by local municipalities, and the development axes are created along highways, separating the diverse green territories. The authors offer a schematic model of the urban forest and urban area development for Riga city, which will ensure the preservation of forest areas and the non-confluence of urban areas.

Key words: urban forests, green belt, 5 Fingers Plan, urban development, social functions.

Introduction

During the last 100 years, global and radical changes have been occurring in society, and a large share of committed rural people has become typical city or town inhabitants. The processes of urbanization cause a lot of challenges and issues (the merging of urbanized territories, decrease of the areas of green spaces and their quality, and their fragmentation) revealed in the interaction of cities and their peripheries (Carreiro *et al.*, 2008). The resilience of the cities is argued due to the socio-political consequences, climate change and also COVID-19 pandemics. Nature-based solutions are more frequently considered to be sustainable (Bayulken *et al.*, 2021). The density of many built-up areas is increased, but not expanded at the expense of the green spaces. In the green territories of cities and their suburbs, alongside with environment protection, the social function has become one of the most vital functions diminishing the role of commercial wood production. The dominance of the social function of forests is critical, particularly under the Covid-19 conditions; and not only specialists are aware of the values of the forest, but also a wider community is developing awareness of the values of nature and the significant role of forest management.

The impact of COVID-19 has disclosed how critical for the wellbeing of people are the urban forest territories located on the outskirts, and, under the emergency situations, they are in a much higher demand than ever before. The recreation areas in urban forests are extremely significant. Taking into account the latest experience of the virus prevention in the nature park Ogres Zilie kalni gained by I.Kraukle working as a park director, the development of disperse recreation zones that limit the concentration of visitors, is particularly important.

In terms of spatial planning, comprehensive and

integrated planning of the city and its periphery shall be addressed (Akmar *et al.*, 2011; Hawkins & Selman, 2002). Intensive balancing and satisfaction of needs is vital that can be achieved via a modern approach for spatial planning: an integrated evaluation of environmental, economic and social aspects (for instance, transport planning, use of sustainable resources, pollution reduction, landscape planning, taking into account the interests of the community (Konijnendijk *et al.*, 2006). In the 21st century, the structure of the 'City Fabric' has become looser resulting in less used areas within the city of Riga. However, zones of intensive urbanization are appearing in Pieriga that is located very close to Riga. Diverse phenomena such as economic, social and physical links, housing, employment and recreation are functioning beyond the administrative borders of Riga and Pieriga. The current experience of Latvia shows that, contrary to the experience obtained by other European countries (Akmar *et al.*, 2011; Carreiro *et al.*, 2008), too little attention has been paid to the planning of urban forests.

The urban forest is a natural or partly natural, or artificial ecosystem in all its stages of development. It is dominated by trees, the height of which in a particular location and time can reach at least 7 m and the projection of its current or potential canopy is at least 20% of the area covered by a forest stand (Meža likums, 2000). In the urban forest, the main functions are the social and environmental ones. The urban forest serves as a public outer space in an administrative environment and the urban territory beyond it.

A high number of residents are concentrated in a small territory adjacent to Riga. In the past, we could talk about urban forests within the territory of Riga and suburban forests in the periphery of Riga. The

urban forests near the living areas were used mainly for walking and cycling on workdays, but suburban forests for recreation on weekends, reaching the forests by cars or public transport.

The urban forests are a constituent component of the multi-functional urbanized territories that improve life environment in the city. Forests are sustainable and self-sufficient structures on condition that people do not interfere with their natural processes. In the city environment, people exert their impact on it even without intensive cutting of trees, but they do that through their constant presence, recreation activities, and emission gases from cars, heating equipment and production facilities (Straupe *et al.*, 2012).

Due to the changes and dispersion in the structure of the populated areas and due to the increase of the number of vehicles used by people, differences between urban and suburban forests have been decreasing. The populated areas have stretched into the suburban forest zones and are accessible via a 15 minute walk. The same 15 minutes are sufficient to reach a suburban forest on the outskirts of Riga by car (Jankovska, 2013). Because differences between the use of urban and suburban forests are decreasing, suburban forests require an equal approach to their planning and management, and they can be considered as urban forests (Jankovska, 2013).

The aim of this study is to analyse the systems of the urban forests in, Vienna, Stockholm, Copenhagen and Riga, which extend to the settlement structures of the cities as 'green fingers' or 'wedges', or separate the city settlement areas that tend to expand and merge and to offer a model for Development of Urban Forest Areas in Riga, on the basis of the international experience. The 'green wedges' of urban forests is a mode of planning with the aim to limit the continuous expansion of urban areas that do not leave space for natural areas that are necessary for maintaining the environmental diversity and provision of services for forest ecosystems.

Materials and Methods

Territories in Vienna, Stockholm, Copenhagen and Riga have been chosen for the analysis of these capital cities with their nearest development zones, including the existing or purposefully developed green areas that restrict the merging of the urban areas. The selected cities are similar to Riga with many of the city forests, other green and water areas. Similar urban and suburban development is taking place in the areas, preserving green areas of different scales, with an emphasis on urban forests.

The available planning documents (Wieshofer *et al.*, 2015; Stockholm, 1999; Stockholm City Plan 2018; Stahle, 2002) (and others described more detailed for each city below) characterizing the urban

forest areas, were analysed as well as the city planning documentation and public mapping materials on the green areas in the above mentioned cities have been evaluated and compared. In the study, planning documents from 1990s until present days are reviewed.

Results and Discussion

The Urban Forests in Vienna, Their Planning and Governance

The green areas cover almost half of the territory of Vienna, including a vast range of green structures from small neighbourhood parks and green areas along the streets and in the yards, and trees and alleys to major historical parks, nature protection areas and urban forests near the city border (Erhart, 2002). In 1950s, the territory of Vienna was expanded by attaching large forest areas to it. The purpose of the city politicians was to keep the green belt around the area with the erected buildings, and new and large parks were constructed (Erhart, 2002).

The forests owned by the city of Vienna are being managed by the Office of Forestry and Agriculture. Specific management plans are developed for all these areas. Since 1960, more than 500 ha of forests have been planted for recreational purposes (Weidinger, 2011).

In the City of Vienna, the planning tool is the Law on the Industry of Building, the Community Development Plan and the legally binding Land Use Plan that are combined into one document (Wieshofer *et al.*, 2015).

Informal planning documents that are not authorized by law are: the City Development Plan 94 (Stadtentwicklungsplan 94, STEP 94), the Plan Greenbelt Vienna 1995 and the Plan for Strategic Development of Vienna. The City Development Plan 94 sets the framework for the development of a planned land-use, and it prescribes 11 development axes for the city development, and between these axes large green areas are planned that shall be preserved and united in a network of green structures (Wieshofer *et al.*, 2015). The Vienna Green Belt Plan 1995 demonstrates the network of green areas that shall create a belt around the built-up areas (Erhart, 2002).

It was followed by STEP 05 developed since 2005, and it included the mission statement 'The Green Spaces of the Urban Region' aimed at *Development for Sustainability*. Pursuant to the mission, landscapes are constituent components for the development of the economic region and they form a foundation for protection of long-term high quality standard of living within the city region (Wieshofer *et al.*, 2015).

The purpose of the mission statement "Green Spaces of the Urban Region" is to protect and develop landscapes, and to establish the settlement border of the city territory. The STEP 05 mission statement

“Green Spaces of the Urban Region” remains the same regarding its principles for STEP 2025) (Wieshofer *et al.*, 2015).

When drawing parallels with the case of Riga (described below) and its region, a conclusion can be made that both cities have comparatively large areas of urban forests with all functions typical of urban forests, and these functions are supported by the forest areas, and these spaces are managed by a municipal forestry organization. The planning situation is also similar, as no unified planning authority for the city and its region has been established neither in Vienna nor in Riga. Thus, high quality planning and the use of green spaces and urban forests for community needs are hampered.

Urban Forests in Stockholm and the System of the Green Areas

With the aim to find similarities in the Stockholm case and the Riga case regarding their population number, characteristics of the climate and plant species, this study has characterized the green structure of the capital city of Sweden, Stockholm.

The green structure covers 1/3 of the territory of the city, 60% of the urban forests of Stockholm are owned by the municipality; thus, the use of these areas for the public recreation functions is enhanced.

Earlier, the Swedish urban forests were used mainly for production functions. In 1990s, the social values and functions of forests were identified, and new developments in the management of urban forests appeared. As Falck defines the urban forest, it includes all forests growing in the territory of the city and its suburbs. And he adds that the vegetation of land in urban forests is uncultivated (Rydberg & Falck, 2000).

In the 30s of the 20th century, territorial planning in Stockholm was started, and radial development schemes with wedges of green spaces, separating the development areas, were drawn up. In the city development plan, fingers of intensive settlement were drawn along the highways keeping green wedges of non-urbanized areas between them not to allow merging of the urbanized areas. The green wedges have been developed up to now, and they are extending across the whole region forming easy accessible and usable green areas with high ecological value (Nordh & Olafsson, 2020). As Figure 2 shows, the green structure of Stockholm comprises the natural habitat, green wedges, recreation areas and green connections.

In 1998, the mapping of degraded areas was initiated. In 1999, the mapping of the city of Stockholm under the title ‘Build the City Inwards’ (Stockholm, 1999) was started with the aim to develop the city without its expansion at the expense of the green spaces and urban forests particularly, but through an intensive use of the degraded or rarely used city areas (Stockholm 1999). In the Stockholm City Plan

2018, an increased city density was also stated as a possibility for development (Stockholm City Plan 2018).

In 2001, the City Council approved the first regional development plan for the Greater Stockholm (Nelson, 2009). The regional plan included two main objectives: to form regional development centres and to maintain the green structure and values of the territory within the city and outside of it. The major priority of the Stockholm Plan was to combine and preserve two functions of the green areas: recreation and preservation of biological diversity.

Stockholm has created the Green Map as a planning tool, consisting of three parts: the map of biotopes, the map of reuse of resources, and the map of socio-topes (Xiu *et al.*, 2017) based on the concept of socio-topes that has been introduced into planning (created in 2004 and 2005). The maps of socio-topes are used for planning at the level of boroughs, and they focus on the qualities of urban forests and other green spaces, and on their development. At present, maps of socio-topes have been created not only in Stockholm, but also in Uppsala, Malmo, Gothenburg (Xiu *et al.*, 2017).

Contrary to the concept of ‘biotope’ (ecologically defined environment), the socio-tope has been defined as a homogeneous place (topos) of a particular culture, community or group of individuals (socio) regarding the objectives for the use of that particular place, its social meaning and values. Pursuant to this concept, questions: ‘For whom?’, ‘For what purpose?’ and ‘Where?’ are put (Stahle, 2006).

In the urban environment, the urban forest should be available at the distance of 1 km, providing swimming, fishing, skating and skiing possibilities, cultural-and-historical objects, broad views, waters; or a nature reservation with the area of more than 50 ha (Nelson, 2009; Ståhle, 2010).

The most important requirement for the urban forest is to have a sufficient area in order to meet the needs of the inhabitants of the city and suburbs, to preserve the environment and to provide comfort for people. The objective of the city of Stockholm is to have dense green structures of high quality for the achieving of which the following major strategies are described in the Park Programme (Stahle, 2002):

- Expansion of the green zones,
- Diversity of activities and elements,
- Concentration- renovation of the territories of the existing open spaces, enhancing their quality and accessibility,
- Management for maintaining well-functioning structures.

The map of the socio-tope and the guidelines of the Park Programme have been used for several city planning projects, and based upon them, the maps of

socio-topes and the concept of green wedges have been created in other cities (Uppsala, Malmo, Gothenburg and Helsinki). For the planning and management of the green territories of Riga and other cities and towns of Latvia, it is recommended to use the Stockholm experience for the evaluation of the quantity of the green territories and for enhancing their qualities, taking into account the interests of individuals and community.

The Green Structure of Copenhagen Urban Forests

The Green Network Plan was first drawn up in Copenhagen in 1936. A comprehensive recreation network plan was developed that included a system of nature parks connected in the north and northwest of Copenhagen. The Plan marked territories with highly valuable landscapes and the connecting corridors as greenways and ecological corridors, and the main landscape management principles for them were developed after several decades (Vejre, Primdahl, & Brandt, 2007).

The origin of the regional structure of the Copenhagen 5 Fingers Plan dates back to the 1940s (Cahasan & Clark, 2005). At the end of the 1960s, due to rapid development, the green wedges in several locations had turned into narrow lines, however, in the beginning of the 1970s, the planning and legislative instruments stopped the destroying of the green territories and reduction of areas (Vejre, Primdahl, & Brandt, 2007). The green infrastructure planning at a municipal level is influenced by the national rules and guidelines as well as regional plans (Nordh & Olafsson, 2020).

The 5 Fingers Plan includes several basic principles that contribute to the integration of new green elements into the existing structures of the city and its suburbs (Cahasan & Clark, 2005):

- The urban environment is developed into narrow zones-fingers,
- The undeveloped green wedges are retained between the development fingers,
- The development of the fingers occurs along the public transport zones (with a focus on railroads),
- The peripheral urban areas are developed as individual elements of the common structure (as 'individual pearls in a bead'),
- The population shall reside close to the green spaces.

H. Verje states that, in general, the new landscapes can be characterized as modern gardens, forest recreational landscapes with some pasture and arable soil remains (Vejre *et al.*, 2007). The functionality of the landscape has also changed respectively: the primary function is recreation, followed by the function of the nature biotopes for providing ecosystem services, then housing functions follow and, to a limited extent, production functions do.

The latest versions of the icon of the 5 Fingers Plan encourage us to reconsider also the situation in the Greater Riga where some parallels can be drawn with the green structures of Stockholm, Copenhagen and Vienna and their green structures in the peripheries.

Characterization of Urban Forests in Riga

In the opinion of the architect Arnolds Lamze, revealed in the General Plans of Riga back in 1924 and 1936, the plan shall be developed for a larger economic region (Lamze, 1932). The urban forests in Riga and the Greater Riga have been retained and expanded due to the intentional afforestation of dunes. Until the 1980s, for the purpose of restricting erosion caused by winds, mainly pines (*Pinus silvestris*) were planted, and their plantations were supplemented by grasses, willows (*Salix*), sea buckthorn (*Hippophae*) and other shrub species (Mangalis, 2004). Preservation of the forests was also fostered by the Soviet normative enactments, strictly limiting production activities in urban and peri-urban forests with the aim to create the 'green shield', as well as to keep timber resources that could be available easily and quickly in case of military conflicts.

The lifestyle area of the urban environment of Riga and its periphery that includes the shared 'urban fabric' of the City municipality and the neighbourhood municipalities, and the green territories create a unified structure that is not limited by any administrative borders.

The scheme of the settlement areas and forest wedges has been included in the map, schematically specifying densely populated, larger and smaller spaces, and the urban forest in Riga and its periphery. Thus, a focus is on the urbanized territories, which extend from Riga to the suburbs of Riga along the main road axes, showing the scattered urban forests in the periphery of Riga, as well as the dense wedges which are stretching from the green way of Riga.

Having generalized the scheme of the settlement areas in Riga and the forest wedges, the authors of this article offer a model for the territories of the urban forests in Riga and its periphery. In the scheme of the urban forests and green territories of Riga, the authors have found some similarity with the 5 Fingers Model of the Greater Copenhagen, and even five coastal extensions of settlement are present in this scheme.

As Figure 1 shows, the Riga Model includes radial extensions of the settlement areas, elements of the circle of the urban forests supplemented and connected with forest wedges structures.

Having compared the above model with the recommendations for the spatial planning of the Riga Planning Region, drawn up in 2007, the author I. Kraukle argues that the green wedges do not extend from Riga urban area, but, on the contrary, they extend into Riga from the large forests of the green belt, surrounding Riga.

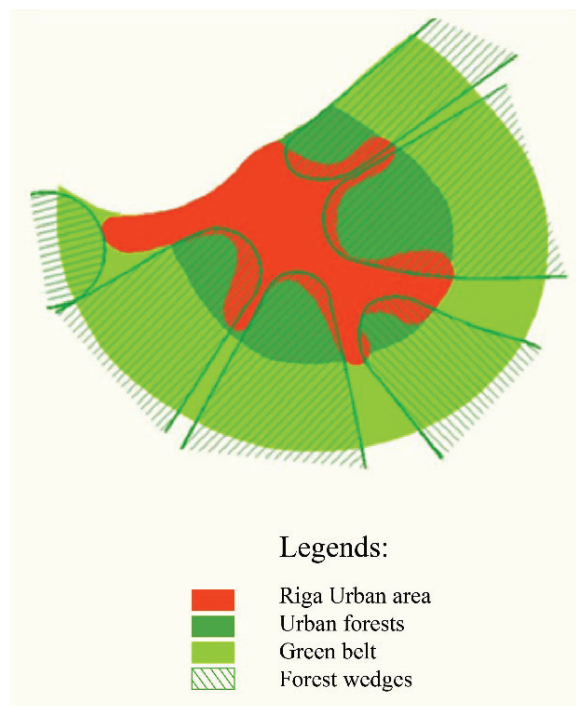


Figure 4. Model of Territories of Urban Forests in Riga (Authors made, source Kraukle, 2013) (Kraukle, 2013).

The scheme of the green network of Riga included in the Strategy for Sustainable Development of Riga City 2030 shall be supplemented. In spite of the fact that the outer green circle is outside of the border of Riga, the existing link between the forests of the green belt, which provide a higher vitality and effectiveness of the urban forests, is not depicted.

Kraukle reveals (Kraukle, 2013) the radial settlement extensions and the circle of the urban forests that separate these extensions and are actually created by the green zone forest wedges that sprawl to the Riga urban area.

The level of provision with amenities and facilities in the urban forests of the Riga urban area is still low, and insufficient attention is still paid to them. In many places, the only way how to protect the forest from the anthropogenic load is to update the existing amenities and facilities (Bell, 1997; Emsis, 1980). Also, measures for the soil re-cultivation/ tillage are critically necessary in many places in order to prevent soil erosion (Emsis & Tuktens, 1988).

During the recent years, the municipalities of Riga and Pieriga have been creating recreation zones within the territories of the urban forests.

Conclusions

Viable forest territories, covering spaces with sufficiently large areas and tree stands of diverse

structures and ages, and biological diversity shall be maintained not forgetting about amenities and facilities for recreation needs of the population. Diverse smaller structures (green corridors) that connect the urban forests and the largest parks shall be created and maintained. The green corridors are vital for the maintenance of biological diversity in the cases of excessive fragmentation of the green territories. The accessibility of the green territories via walking or driving 10–15 minutes becomes especially important.

As the analyses of the international experience shows, planning in European cities takes place simultaneously with the planning at the levels of the urban and suburban areas or regions. It is so in Copenhagen and Stockholm where the planning and governance of large green structures, including the urban forest territories, is implemented more successfully. All the examples, discussed above, refer to the territories around the country capitals. These particular territories of increased development include large green spaces, which are preserved in spite of the expansion of the urban areas.

In Vienna, the planning documents—are legally binding or informal. The informal planning documents include the plan of the Vienna Green Belt 1995 and the City Development Plans for a decade that—prescribe diverse activities in each stage for preservation and development of the green spaces.

Since 1998, in the plans of the City of Stockholm, the focus has been on the mission “Build the City Inwards” that emphasises the need to develop the city without any expansion of its territory, particularly preserving the green and urban forest areas and actively reusing the degraded and almost abandoned city territories. Stockholm has been using the Green Map as a planning tool since 2004 including information on biotopes, renewal of resources and socio-topes.

The Copenhagen Green Network Plan includes a system of interlinked nature parks, ensuring non-confluence of urban areas. The Copenhagen 5 Fingers Plan prescribes the development of the urban environment in narrow zones or fingers following the zones of public transport between which undeveloped green wedges are preserved ensuring that people have a possibility to live very close to the green spaces.

Planning documents in Riga do not strengthen and preserve the status of green territories enough. A territorial planning document in Riga is necessary in order to expand the status of the green territories not allowing their reduction. The Riga Model presented by authors will provide preservation of forest wedges, which will separate urban areas in Pieriga – Riga urban area.

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PROPERTY EVALUATION BASED ON AMBIGUOUS LOGIC THROUGH BUILDING INSPECTION IN SÃO PAULO CITY, BRAZIL

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Abstract

The civil engineering branch is strongly related to the development of the countries and there is still a lot of information available in the buildings constructed. However, these data are dispersed without proper treatment. On the other hand, if these real estate data are reorganized to discover behavior parameters, these properties' values can be predicted and still work as data and causal relationships between explanatory variables. The purpose of the research is to use construction inspection strategies associated with artificial intelligence to predict the market value of a residential apartment. In this academic experiment, only 6 samples of residential apartments are used. Those samples are located in the Lithuania Republic square at Vila Zelina neighborhood, in São Paulo, Brazil, a source in February 2021. The method uses the results of the inspection of civil engineering and converts them into linguistic terms. The result considers the imprecision, uncertainty, and subjectivity of human expression combined with artificial intelligence and civil engineering. To test the feasibility of the process, a comparison is made between the market values of the samples and the values predicted by the Fuzzy logic. Thus, the good results derived a Main Percentage Absolute Error (MAPE) of 5%, the mean absolute error (MAE), root-mean-square error (RMSE), and determination coefficient (R^2) of 0.99.

Key words: appraisal, algorithmic, civil engineering, inspections, fuzzy logic, baltic countries.

Introduction

In the Baltic area, the real estate market and civil construction are closely related to each other (Apanaviciene, Urbonas, & Fokaides, 2020), towards progress and development (Mishra & Kauškale, 2017). The liberty has been consolidated, as well as the possibility for different choices has become a reality among citizens of the Baltic countries (Grāzin, 2020), added to the process of access to housing that also undergoes changes after the Soviet era (Vihalemm, Juzefovičs, & Leppik, 2020). In Latvia, there is an academic proposal dealing with improvements in the process of evaluating residential properties with the use of heuristics, artificial intelligence combined with building inspection, and civil engineering techniques (Surgelas, Pukite, & Arhipova, 2020). By the way, it is relevant in the Baltic since in these countries there is a strong inheritance from a hard time, where individuals for many years had little or no possibility of the choices (Anušauskas *et al.*, 2007). This is because Latvia, Estonia, and Lithuania suffered something similar, the consequences of the Ribbentrop-Molotov Pact, and the World War II reach of the Baltic countries (Bumblauskas *et al.*, 2013; Cadzow, 2020). At the end of the war, Latvia, Lithuania, and Estonia came under the Soviet side of the iron curtain (Baltijos Kelias, 2020; The Baltic Way, 1989–2014). Nonetheless, the heuristic property experimental valuation method was applied in 2019 in Riga city, in 2020 in Jelgava city, both cities located in Latvia. In 2021, the methodology simulation process takes place in Niterói city, Rio de Janeiro and in São Paulo city, in Brazil. In 1982, the Freedom Monument was built in the same square as shows Figure 1. It is a cultural heritage, the commemorative monument

for the 50th anniversary of Lithuanian immigration, and a replica of the Freedom Monument in Kaunas, Lithuania. By the way, Lithuania Republic square was chosen in this article because it is a symbolic civic and cultural landmark between Lithuanian, Latvian, and Estonian immigrants. In 2016, the Lithuania Republic square received a proposal to become a civic square Figure 2. Furthermore, that square is a landmark for the sociability of these immigrants and descendants of Lithuanians, Latvians, and Estonians. By the way, heuristics are ideal for solving poorly structured problems (Meech & Veiga, 1998). In essence, the use of the type of linguistic description employed by human beings, and not quantified variables, allows the treatment of systems that are too complex to be analyzed using conventional mathematical terms. In this context, they also provide acceptable solutions to complex problems. And it is much better if supported by artificial learning algorithms (De Jong, 1988; Agrawal, Rakesh, & Ramakrishnan, 1994). These heuristics can be solved using Fuzzy logic: that method was introduced by Lotfi A. Zadeh. Besides, from the point of view of logic to fuzzy, the main function of linguistic variables is to provide a systematic way for an approximate characterization of complex or ill-defined phenomena. This cognitive heuristic manner influences the decision, which starts to be taken from a balance between reasons for and against the various alternatives (Kirsh, 2009). Because, in the particular case of the real estate market, it has some differentiating characteristics, such as strong influences of the location and heterogeneity of the assets (Cheng, Lin, & Liu, 2020). These characteristics, once transformed into association rules, can reveal patterns of consumption or sales behavior (Suchacka & Chodak,

2017). The process of generating association rules is based on “support” and “confidence”. Thus, Weka Software will generate association rules that will present a pattern of behavior, by “apriori” algorithm. Apriori is an algorithm for mining frequent items and learning association rules in relational databases. The algorithm identifies frequent individual items. These sets of frequent items determined by Apriori are used to determine association rules that highlight general trends in the database. Thus, the set of items is considered “frequent” if it meets the support limit specified by the user (Motta, 2010). In this context, the “support” of item “I” is the number of transactions containing “I” divided by the total number of transactions. This “confidence” measures how often items in “Y” appear in transactions that contain “X”. The “confidence” is calculated as the number of transactions containing “X” and “Y” divided by the number of transactions containing “X”. Thus, a “strong rule” can be defined as a description of regularity, with high confidence for numerous examples, a “weak rule” represents a regularity with high confidence, for some examples (Rathjens, 1996). Not only, that is, not all rules discovered from a set of transactions are interesting or useful. To assess the degree of interest (IR) of a rule we will have to observe (conf.), (lift), (lev.), (conv.), where: (conf.) is expected confidence. Lift: is the ratio, in percentage terms, between confidence and expected confidence. Likewise, the higher the Lift, the greater the relevance of this rule. Leverage (lev.): indicates the difference between actual and expected support for an association rule. This measure varies between -0.25 and 0.25, the higher this value, the more interesting the rule will be. Conviction (conv.): it will be used to verify whether the rule obtained using these two measures is relevant. Similar to the confidence measure, conviction represents the associative “power” between the antecedent and the consequent of a rule. Thus, this research is a part of a doctoral thesis in Latvia and the purpose of this article is to use simple building inspection strategies to predict the market price for residential apartments. Moreover, abnormalities taken from inspection (inside) were described with the linguistic terms introduced and Index anomalies. Very light (excellent) $5.00 > IA \geq 4.50$; Light (good) $4.50 > IA \geq 3.50$; Medium (medium) $3.50 > IA \geq 2.50$; Serious (bad) $2.50 > IA \geq 1.50$; Very serious (terrible) $1.50 > IA \geq 1.00$ (Pedro, Paiva, & Vilhena, 2008). For this, 6 samples of residential apartments are used in the São Paulo city, Brazil in February 2021. Thus, the process of appraisal is followed by the Fuzzy method (Zadeh, 1965) combined with the incorporation of the association rules originated from Weka’s “apriori” algorithm (Frank, Hall, & Witten, 2017). By the way, the Apriori application is an implementation of Borgelt

(2003), of the traditional Association Rules algorithm, of the same name developed by Agrawal et al. (1993). Further up, in Mandani defuzzification process, the interpretation of the ambiguous set of output inferred carried out, to obtain a numerical value (Srishti & Seba, 2020). Thus, the InFuzzy software (Posselt, Frozza, & Molz, 2015) was chosen to discover the prices of the residential flats. Furthermore, Iserhard et al. (2019) suggested the development of quality for performance analysis of a construction company using fuzzy logic. To check the reliability of the method, the comparison between the market values of the samples and the values predicted by the fuzzy logic is used. For this, the Main Percentage Absolute Error – MAPE was calculated.

Materials and Methods

This research was conducted using as samples 6 residential apartments in São Paulo city during February 2021. The samples contained one until 3 rooms. Then, for a better understanding of the methodology, it was divided into 5 phases described as follow. **Phase 1** – Investigation for the data source accessible on the World Wide Web. Residential apartment offers are available on real estate sites in the region under study. After the preselection of samples, the inspection of these samples took place. During the visit to the surveyed properties, the standard engineering inspection form was applied (Fig.3). That form was filled in according to the visual observations available at the time of the technical visit. The variables chosen are a function of the proximity of the Lithuania Republic square and marketplace surrounding of that place, the number of rooms, and the state of condition of the building and apartment. Thus, the variables independents are the following: 1) apartment area (Area), 2) conservation state in the apartment (Consv_ap), 3) building conservation (Consv_build), 4) view to Lithuania Republic square (View), and 5) the number of rooms (rooms). The output Y is the “Price” of the apartment (Euro m²). **Phase 2** – The data were organized by the author to aggregate the attributes of each apartment. The author created the attribute-Relation File Format (ARFF) file on the Notepad++ with the content of the price/square meter ratio. The ARFF is an ASCII text file that describes a list of instances that share a set of attributes. A file ASCII is an essentially raw text, just like the words you are reading now. **Phase 3** – The rule system was developed on the basis of the combinations of inputs (total of 5), which were assigned a weight of 1 to establish relevant equality for each rule and reach associations able to optimize the parameters (Abreu *et al.*, 2015). The application of the ARFF file is launched in the Weka software (Frank, Hall, & Witten, 2017). Thus, the entire process of

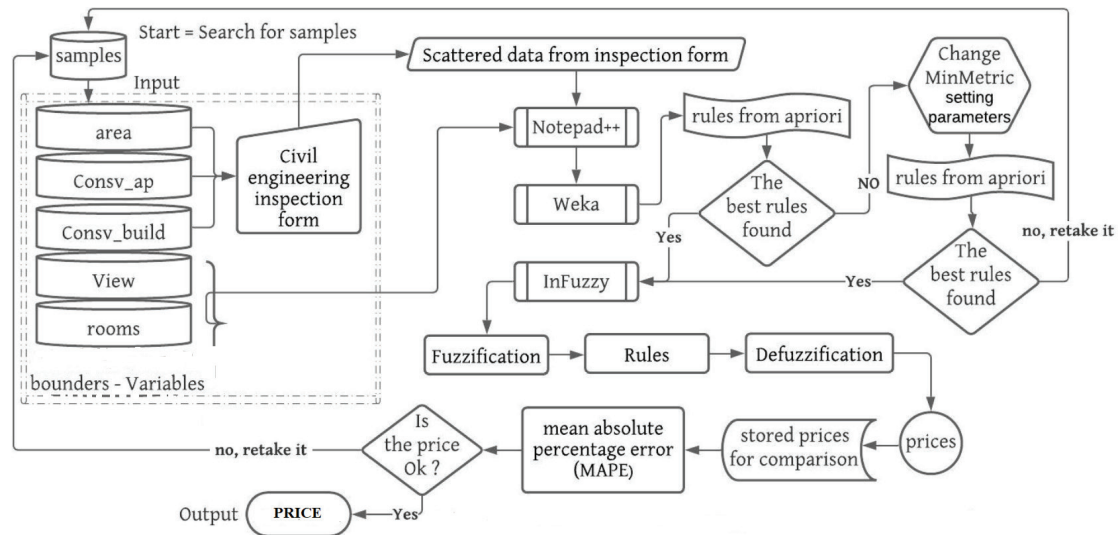


Figure 1. The methodology used for forecasting the price of the residential apartment.

Source: author.

generating association rules is based on “support” and “confidence”. In this direction, Weka Software will generate association rules that will present a pattern of behavior, by “apriori” algorithm. The support limit was defined by this researcher as 0.25 (25%). That is, the set of frequent items occur together in at least 25% of all transactions in the database searched in Vila Zelina, in São Paulo (Minimum support: 0.25). The minimum confidence level defined by this researcher was 95% (Minimum metric <confidence>: 0.95). The number of association rules was initially defined by the researcher in 1215 rules (numRules: 1215). **Phase 4** – In this phase the InFuzzy software was used, which is a tool for the development of diffuse system applications. In this task, the author inserted the association rules of interest chosen for this research, as selected in Step 3. The Fuzzy sets were done and follow described. For the linguistic variable: **1) (Area)** The linguistic terms adopted was a function of the characteristics of the inspected apartments: low, normal, big; The pertinence function chosen was the Gaussian, for which the mean and standard deviation of the sample samples are calculated. Before that, the “Chauvenet” exclusion criterion is adopted. In the base variable, the parameters adopted vary from 0 to 150 mere squares. This is due to the square footage of the surveyed samples not exceeding 130 square meters around Lithuania Republic square. **2) (consv_ap)** The linguistic terms adopted was a function of the characteristics of the inspected apartments and buildings: terrible, bad, medium, good, excellent. The pertinence function chosen was the left ramp, triangle, right ramp and trapezoidal. In the base variable, the parameters adopted vary from 0 to 5. These parameters are due to accordingly (Pedro, Paiva, &

Vilhena, 2008). **3) (consv_build)** The linguistic terms adopted was a function of the characteristics of the visual inspected buildings: new, renewed, and old. The pertinence discreet function was chosen. Thus in the base variable, the parameters adopted vary from 1 to 3. The inspection was visual with an emphasis on the appearance and external condition of the buildings. **4) (view)** The linguistic terms adopted was no view, indirect, direct. The pertinence function chosen was the left ramp, triangle and right ramp. Thus in the base variable, the parameters adopted vary from 1 to 3. This classification attributes the variable “view” to the square as a relevant factor. **5) (rooms)** The linguistic terms adopted was small, normal, good. The pertinence function chosen was the discreet. Thus in the base variable, the parameters adopted vary from 1 to 3. This classification is a function of the typology found during the inspections in the apartments samples, that is, there are samples with 1, 2, and 3 rooms. **Phase 5** – The intention of this phase was to understand the precision of the experimental model. It is about reporting the results of step 4 and checking for compatibility. This compatibility and precision of these results were accomplished by the following metrics, the mean percentage absolute error (MAPE). Figure 1 illustrates the methodology used to forecast the price of the residential apartment.

Results and Discussion

Phase 1 – Selecting scattered data.

Of the six (6) apartments sampled, thirty seven (37) construction items were analyzed visually, involving various specialties within the field of engineering science (Fig.3). Abnormalities observed in the inspection (inside of apartments) were described

Table 1

Results of inspection on six residential apartments in São Paulo city. Source: author

Variables			The linguistic term used in “consv_ap”	The linguistic term used in “consv_build”	Original price offered in the real estate market (Euro m ⁻²)
Index: consv_ap	Area (m ²)	Index: consv_build			
4.79	68	1	excellent	new	815.73
3.96	60	2	good	old	1,040.06
3.95	93	1	good	new	1,292.31
4.33	70	2	good	renewed	1,045.56
4.63	76	1	excellent	new	2,231.25
4.63	52	1	excellent	new	1,037.10

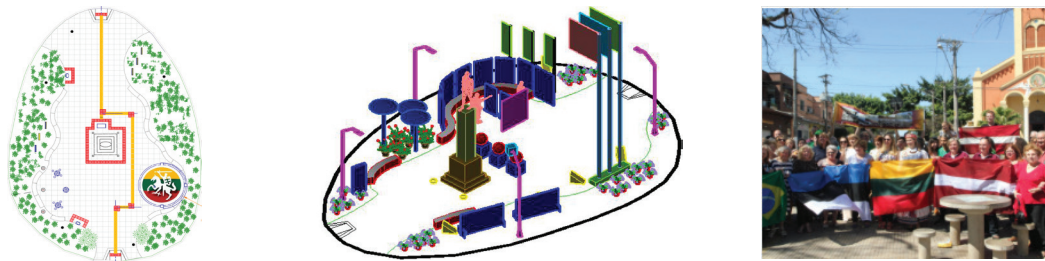


Figure 2. New Civic Square Project.

Source: Architect and Urban Planner Flavia Maria Achão Surgelas, 2016.

linguistic terms. A score of visual problems was created. Very light (excellent) $5.00 > IA \geq 4.50$; Light (good) $4.50 > IA \geq 3.50$; Medium (medium) $3.50 > IA \geq 2.50$; Serious (bad) $2.50 > IA \geq 1.50$; Very serious (terrible) $1.50 > IA \geq 1.00$ according to Pedro, Paiva and Vilhena (2008).

Phase 2 - Preparing files to association rules.

This author created the ARFF file in Notepad ++ with the price / square meter ratio. Below there is the display of the ARFF. This phase had the purpose of preparing the rules for price assessment. Then, phase 3 starts with the rules construction. The rule system was developed on the basis of the combinations of inputs, which were assigned a weight of 1 to establish relevant equality for each rule and reach associations able to optimize the parameters.

Phase 3 – Generating association rules.

By Weka software, with minimum support: 0.25 and minimum confidence level set at 0.95. So 1,215 rules were generated by the data mining / learning algorithm. In this situation the 67 best rules following in the same confidence level were chosen with “price”

as a conclusion and the system used the InFuzzy rule block. From this, the preselection of the association rules was made and fed the Weka Software. Only then rules can be introduced into the InFuzzy Software. The rule system was developed on the basis of the combinations of inputs, which were assigned a weight of 1 to establish relevant equality for each rule and reach associations able to optimized the parameters.

Phase 4 - Fuzzy Inference process.

The price of the property is assessed, using the InFuzzy software for modelling the diffuse system. Inference was used Mandani methodology. The defuzzification methods were used in Mamdani inference: center of gravity of the area (centroid), method (Dernoncourt, 2013; Abreu *et al.*, 2015). By the analysis of the conventional statistical operation, the parameters of the variable “area” was found after verification by the exclusion criterion “Chauvenet”. Chauvenet’s criterion brand the premise that the values are in a dataset normally distributed. Hence, five samples were used. For this, the calculation below defines the maximum and minimum values, mean,

```
@relation price_per_square_meter
@attribute area_m2 {normal,big,low}
@attribute cons_ap {terrible,bad,medium,good,excellent}
@attribute cons_build {new,renewed,old}
@attribute view {no_view,indirect,direct}
@attribute rooms {small,normal,good}
@attribute price? {low,average,expensive}

@data
normal,excellent,new,no_view,normal,low
normal,good,old,no_view,normal,average
big,good,new,indirect,good,average
normal,good,renewed,no_view,good,average
normal,excellent,new,no_view,normal,expensive
low,excellent,new,no_view,normal,average
```

Sample		CONSERVATION STATUS					1 Euro = R\$ 6,49 Euro exchange rate in 02/16/2021		
A – Identification		City: SAO PAULO	Country : BRAZIL	Address/ Place: VILA ZELINA					
B – Basic description		Room: 2	Area 68 m ²	Price: 360,000.00	5,294.12	Real m ²	Data: February 2021		
C - Functional elements anomalies							815.73	Euro m ²	
		Anomalies							
		Very light	Light	Average	Serious	Very serious	Not applicable	Weight	Score
		(5)	(4)	(3)	(2)	(1)			
Building									
1.	Structure	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	X 6	30
2.	Coverage (roof)	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	X 5	20
3.	Facade elements (producing elements)	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	X 3	12
Others common parts of the buiding									
4.	Walls	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	X 3	15
5.	Floor coverings	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	X 2	8
6.	Ceilings	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	X 2	10
7.	Stairs	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	X 3	15
8.	Windows and doors	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	X 2	10
9.	Fall protection devices (guarding against falls upper storeys)	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	X 3	12
10.	Water distribution facility (Water services)	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	X 1	5
11.	Sewage services/ house drainage system	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	X 1	5
12.	Gas installation (gas services)	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	X 1	5
13.	Electrical and lighting services	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	X 1	5
14.	Communication installation and against intrusion detection	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	X 1	4
15.	Elevators installation (lifts)	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	X 3	15
16.	Fire safety installation/ fire safety system	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	X 1	5
17.	Waste disposal facility/ household waste (trash chute services)	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	X 1	5
Apartments (unit)									
18.	External walls	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	X 5	--
19.	Internal walls and partitions	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	X 3	15
20.	Outdoor floor coverings	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	X 2	--
21.	Insite floor covering (internal floor coverings)	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	X 4	20
22.	Ceilings	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	X 4	20
23.	Internal stairs	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	X 4	--
24.	External windows and doors/ front doors	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	X 5	25
25.	Internal windows and doors	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	X 3	15
26.	Protection and shading devices of windows	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	X 2	--
27.	Fall protection devices/guarding against falls from upper storeys	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	X 4	--
28.	Sanitary equipment	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	X 3	15
29.	Kitchen equipment	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	X 3	15
30.	Water distribution facilities / water seervices	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	X 3	15
31.	Wastewater drainage instalation / sewage services	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	X 3	15
32.	Gas instalation /gas services	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	X 3	15
33.	Electrical instalation (electricity services)	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	X 3	15
34.	Communication facilities and against intrusion / alarm services	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	X 1	3
35.	Ventilation instalation / ventilation services	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	X 2	--
36.	Heating/ cooling services	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	X 2	10
37.	Fire safety instalation (fire safety services)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	X 2	--
D Determination of anomaly Index (defect index)									
Is there any situation that puts a serious risk to safety and health?		YES	NO				Total of scores	a	379
		<input type="radio"/>	<input checked="" type="radio"/>				Total of weights	b	79
					Anomaly Index			a + b	4.79

Figure 3. Conservation status form – example: sample 1.

Source: Adapted from (Pedro, Paiva, & Vilhena, 2008).

the standard deviation of the variable “area”. These values were used to write the Gaussian function in the InFuzzy software. Through the Mamdani inference system, the indicators of Gaussian functions were pointed out as better compared to those of triangular

functions, regardless of the defuzzification method applied. Table 2 shows an example of the Fuzzy sets. Thus, the computer simulation on In Fuzzy software starts and Table 3 shows the output variable (price) and the result becomes the center of gravity reference

Table 2

Summary Fuzzy sets. Source: author

	Variables	Range	Classification	Parameters			Function
Input	AREA	[0, 150]	low normal big	0.00 69.83 80.23	59.44 14.09 140.00	Left ramp Gaussian Right ramp	
	CONSV_AP	[0, 5]	terrible bad medium good excellent	1.5 2.5 3.5	0.0 2.0 3.0 4.0 4.5	1.5 2.5 3.5 4.5 5.0	Left ramp Triangle Triangle Trapezoidal Right ramp
	CONSV_BUILD	[0, 3]	new renewed old	1 2 3			Discreet Discreet Discreet
	VIEW	[0, 3]	no view indirect direct	0.8	0.5 1.65 2.1	1.2 2.5 3.0	Left ramp triangle Right ramp
	ROOMS	[0, 3]	small normal good	1 2 3			Discreet Discreet Discreet
Output	PRICE	[0, 2200]	low average expensive	800	150 1350 1900	900 2000 2200	Left ramp Triangle Right ramp

Table 3

Simulation in InFuzzy. Analyses were performed using the statistical software Infuzzy. Source: author

area	consv_ap	consv_build	view	room	predicted price
68.00	4.79	1.00	1.65	2.00	1,383.33
60.00	3.96	2.00	0.50	2.00	1,383.33
93.00	3.95	1.00	1.65	3.00	1,383.33
70.00	4.33	2.00	0.50	3.00	1,383.33
76.00	4.63	1.00	0.50	3.00	1,383.33
52.00	4.63	1.00	0.50	2.00	1,396.94

Table 4

Simulation in metric error. Source: author

price (Y)	price forecast (Yt)	Y-Yt (Euro/m ²)	(Y-Yt)/Yt	(Y-Yt) ²	abs(Y-Yt)	[(Y-Yt)/Yt] ²
815,73	1383,33	-567,60	-0,70	322169,76	567,6	0,48
1040,06	1383,33	-343,27	-0,33	117834,29	343,27	0,11
1292,31	1383,33	-91,02	-0,07	8284,64	91,02	0,00
1045,56	1383,33	-337,77	-0,32	114088,57	337,77	0,10
2231,25	1383,30	847,95	0,38	719019,20	847,95	0,14
1037,10	1396,94	-359,84	-0,35	129484,83	359,84	0,12
				1410881,29	2547,45	97%
				272,50	134,08	5%
				RSME	MAE	MAPE

point. The rules association from Weka were written in InFuzzy software. Where:

Calculation of sample average	(\bar{x}) =	69.83 m ²
The standard deviation of the sample.....	(S) =	14.09
Sample – maximum area found	Max	93
Sample – minimum area found	Min	52.00
Sample numbers	(n) =	6
Degrees of freedom	($n-1$) =	5 (with 80% confidence)
Percentile values for Student’s t-distribution.....	(tc) =	1.65 (table value)

Confidence limits were defined by the Chavenaut criterion, according to the following model.

$$X_{maxmin} = \bar{x} \pm tc \times \left(\frac{s}{\sqrt{n-1}} \right) \Rightarrow \begin{matrix} X_{max} = 80.23 \text{ m}^2 \\ X_{min} = 59.44 \text{ m}^2 \end{matrix}$$

Thus, the defuzzification procedure by centre of mass shows the end process variable (Price at 1,396.94 Euro m⁻²)

Phase 5 - Interpretation of the precision of the experimental model.

The result achieved for the prices assessments has a MAPE of approximately around 5% (Table 4). Furthermore, the experimental data obtained using inspection engineering combined artificial intelligence were used to test the fuzzy models. These prices were compared using the mean absolute error (MAE),

root-mean-square error (RMSE), and determination coefficient (R²) of 0.99.

Moreover, the average value of the listed prices of 1,243.67 Euro m⁻² is compared with the average price of the fuzzy model of 1,396.94 Euro m⁻², it is clear that the system generated differences ranging from 10% to 12%. In the case of real estate values, this percentage of 10% to 12% can be seen as a normal negotiable variation of the price. The main variations in price have significant influence of conservation of the building involving various aspects within the field of engineering. This is therefore, a common practice for negotiation during a sale.

Conclusions

This research demonstrates that the heuristic knowledge of a civil engineering experiment can be translated into a system to estimate, with the aid of artificial intelligence tools, the price of an apartment in the real estate market. In this sense, the prices obtained by the model using six properties in Vila Zelina, São Paulo, Brazil were very close to those followed by the sellers. Moreover, the linguistic terms obtained in a civil engineering inspection were transformed in indexes and included in inference equations to obtain a conclusion. Consequently, with regard to the linguistic rules of human behavior, this research concludes that the use of fuzzy logic in the evaluation of property prices is a relevant method and generates significant results close to the market reality. Due to the know-how of real estate brokers, the result found in the survey seems very consistent.

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THE IMPACT OF CROP ON GHG EMISSIONS FROM CLAY SOILS: CASE STUDY OF LATVIA

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Abstract

Agriculture is a source of three primary GHG: CO₂, CH₄ and N₂O. In order to reduce agricultural GHG emissions, agricultural practices have to promote sustainable land management by helping to prevent soil erosion and creating the potential to increase soil carbon stock. Sustainable soil management includes reducing tillage and introducing legumes in crop rotation. The aim of the study is to identify the impacts of the soil tillage and the cultivated crops on formation of GHG emissions. The study site has 24 experimental fields where two types of soil tillage have been used and four crops were grown (wheat *Triticum aestivum*, rape *Brassica napus*, beans *Vicia faba* and barley *Hordeum vulgare*). Soil humidity, soil temperature and measurements of GHG emissions have been carried out during the plant vegetation period from 2018 to 2020. GHG emissions were measured using Picarro G2508. A total of 460 measurements of GHG emissions were made in 2018, 2019 and 2020. The minimum value of N₂O emission is -19.5 g ha⁻¹ day⁻¹, but the maximum is 273.4 g ha⁻¹ day⁻¹. CH₄ emission has a minimum value of -84.8 g ha⁻¹ day⁻¹, and a maximum of 514.1 g ha⁻¹ day⁻¹. The minimum value of CO₂ emission is -13.0 kg ha⁻¹ day⁻¹, but maximum of 1026.7 kg ha⁻¹ day⁻¹. The results of CO₂, CH₄ and N₂O emissions show a significant discrepancies between the arithmetic mean and the median values which indicates the observed extreme values. Kruskal-Wallis test showed statistically significant differences in GHG emissions by crop groups.

Key words: GHG emissions, crop production, soil tillage, agriculture GHG emissions.

Introduction

In line with the 17 Sustainable Development Goals set by the United Nations, the world population must be able to provide while reducing GHG emissions and reaching climate neutral economy. These objectives should be achieved through transforming existing approaches of farming practices (Sachs *et al.*, 2019). Crop production occupies 12–14% of the available land area. Since 1961, the amount of food calories per capita has increased by about a third, while consumption of vegetable oils and meat has doubled. At the same time, the use of inorganic nitrogen fertiliser has grown nearly nine times (Arneeth *et al.*, 2019).

The development of the economy, including agricultural production, will inevitably lead to an increase in atmospheric GHG emissions. In order to reduce the environmental impact on agriculture, it is necessary to understand the effect of soil management and the role of soil in the context of GHG emissions (Valujeva *et al.*, 2016; Valujeva, Nipers *et al.*, 2020; Valujeva, Pilecka *et al.*, 2020) increase in bio-based production is restricted by emission reduction targets set by climate policies. Meanwhile, the changes in Common Agricultural Policy after 2020 offer each Member State to develop targeted and regional specific policies to meet socio-economic and environmental targets at national scale. Sustainable land management requires understanding of trade-offs among multiple demands expecting from agriculture, land use, land use change and forestry sectors. Shifting

from customary crops to crops with higher economic return can give immediate contribution to achieve socio economic targets, but at the same international commitments require maintenance of existing carbon stocks and increase of carbon sequestration capacity which can be achieved by changing farming practices. South-eastern region of Latvia is chosen as a relevant case study to show trade-offs between simultaneous increase in both bio-based production and carbon stock. The aim of the study is to find optimal approach for land use and improvements of management practices in south eastern region of Latvia to simultaneously increase bio based production and carbon stock. We use spatial land use model under different optimisation scenarios. Results show that production can be increased by 35.1%, while carbon regulation function kept constant, but this rises another problem as it has a negative impact on the supply of biodiversity (-9.2%). Agriculture is a source of three primary GHG emissions: CO₂, CH₄ and N₂O. GHG emissions are caused by fermentation processes in the intestines of livestock, manure management, soil management, liming, use of urea. In Latvia, agriculture is the second largest sector behind energy, which contributes to GHG emissions, and soil management is the largest emitter of N₂O emissions – 60.8% (NIR, 2019). Agricultural soils are responsible for 18% of global GHG emissions (Ozlu *et al.*, 2018). Soil emissions depend on the biophysical processes of the soil and the uptake and decomposition of organic substances in the soil. The

main GHG sources are the use of organic and synthetic fertilisers. Nitrogen fertilisers are important for crop production, but the excessive use of fertilisers may increase GHG emissions. Inorganic fertilisers affect GHG emissions from soil, affecting microbial activity and root respiratory processes that affect nitrification and denitrification processes (Ozlu *et al.*, 2018). High ground water levels, poor soil drainage properties and soil sealing contribute to denitrification and N₂O formation (Bouwman *et al.*, 2002). CO₂ is produced under aerobic conditions and is affected by root activity, microbiological processes, plant residues, as well as microclimate, terrain and catalytic properties in colloid solutions of clay (Muñoz *et al.*, 2010). In order to reduce GHG emissions from agriculture and their impact on global warming, agricultural practices need to ensure sustainable land management. Such practices include reducing soil tillage, which helps to prevent soil erosion and creates potential to increase soil carbon stock and can improve CH₄ consumption (Johnson *et al.*, 2007). Although agriculture generates a significant share of global GHG emissions, it can also contribute to climate change mitigation, as a crop rotation has the potential to reduce or at least not generate more GHG emissions from agriculture (Plaza-Bonilla *et al.*, 2018). Introduction of crop rotation in agricultural lands is considered to be a good solution to increase carbon stock (Poeplau *et al.*, 2015). In order to reduce nitrogen (N) losses in the environment and to reduce GHG emissions, alternative crop systems are promoted, assessing both the system and the culture to be cultivated (Autret *et al.*, 2019). By carefully designing and following the rules of sustainable agricultural practice, the change in crop rotation containing legumes and cereals is rapidly reducing demand for N fertilisers (wheat by 13–30%), without reducing wheat productivity or grain quality (Plaza-Bonilla *et al.*, 2017). The cultivation of legume crops has been proposed as a way of reducing GHG emissions because they are able to deposit atmospheric N and thus reduce the need for external or other nitrogen fertilisers. On the other hand, the introduction of rapeseed in the crop rotation has a positive effect as it breaks the cycle of plant pathogens by reducing the need for pesticides to grow future crops (Vinzent *et al.*, 2017). The formulation of GHG emissions depends on a number of factors that determine the amount of GHG emissions that occur at a particular type of management and need to be verified at national and regional scales (Oertel *et al.*, 2016) methane (CH₄). In Latvia, measurements of GHG emissions in the agricultural sector have been launched and are implemented in several directions. Firstly, research on GHG emission reduction measures and develops future scenarios for GHG emissions in Latvia (Kreismane *et al.*, 2016; Lēnerts *et al.*, 2016;

Lenerts, Berzins, & Popluga, 2016; Lenerts, Popluga, & Naglis-Liepa, 2019; Nipers, Pilvere, & Zeverte-Rivza, 2017; Pilvere & Lenerts, 2015; Zeverte-Rivza, Popluga, & Berzina, 2017) and there is a large potential for land to be used in efficient agricultural production. National task is set for the next years in Latvia to retain agricultural land for agricultural production, in order to efficiently manage approximately 2 million ha. The agricultural sector is an important source of nitric oxide (N₂O). Secondly, experimental studies are carried out on farms where CH₄ measurements are carried out and solutions are sought to reduce CH₄ emissions in the livestock sector (Berzina *et al.*, 2017, 2018; Grinfelde *et al.*, 2018; Jonova *et al.*, 2018b, 2018a; Jonova, Ilgaza, & Grinfelde, 2017) to measure the amount of methane (CH₄). Thirdly, field and laboratory studies are being carried out to analyse not only GHG emissions from soil, but also to determine the effect of fertilizers on GHG emissions (Eihe *et al.*, 2019, 2020; Frolova *et al.*, 2017, 2018; Grinfelde *et al.*, 2019). Currently, there is a lack of understanding of the impact of cultivated crops on GHG emissions in heavy clay soils, which occupy most of the Zemgale region, where mainly wheat and rapeseed are grown. The aim of this study is to identify the difference in GHG emissions by crop.

Materials and Methods

Measurements of GHG emissions were carried out in the experimental farm of Latvia University of Life Sciences and Technologies located at Platones parish of Jelgava municipality. The study site has 24 experimental fields where two types of soil tillage have been used (conventional soil tillage with mould-board ploughing at a depth of 22–24 cm and reduced soil tillage with disc harrowing at a depth below 10 cm) and four crops were grown (wheat *Triticum aestivum*, rape *Brassica napus*, beans *Vicia faba* and barley *Hordeum vulgare*). Measurements of GHG emissions (N₂O, CH₄, CO₂) in field conditions have been carried out on clay soil *Cambic Calcisol* according to IUSS Working Group WRB, (2015). Measurements of GHG emissions have been carried out in the growing season of 2018, 2019 and 2020. GHG measurements from agricultural soils were performed using a mobile spectrophotometer Picarro G2508, which allows simultaneous measurements of N₂O, CH₄ and CO₂ gases with an average interval of one second. Measurements were performed in three chambers for each study plot. Non-transparent chambers with a base diameter of 23 cm and a chamber volume of 3 litres were used. The base is made of metal, and its lower edge is sharpened to make it easier to place in the soil. A non-transparent dome is placed on the base (Frolova *et al.*, 2018). The chamber's connections to the Picarro G2508 were made using commercially

Table 1
Values for GHG emissions descriptive statistics

Statistic	N ₂ O, g ha ⁻¹ day ⁻¹	CH ₄ , g ha ⁻¹ day ⁻¹	CO ₂ , kg ha ⁻¹ day ⁻¹
Nbr. of observations	460	460	460
Nbr. of missing values	0	0	0
Minimum	-19.5	-84.8	-13.0
Maximum	273.4	514.1	1026.7
Range	292.8	598.9	1039.8
Median	0.0	-0.4	23.1
Mean	4.8	37.7	66.6
Variance (n)	456.8	5398.3	10971.2
Standard deviation (n)	21.4	73.5	104.7

manufactured stainless steel connections. Soil moisture measurements were performed prior to soil GHG emissions measurements using the Lutron soil moisture meter PMS-714, which measures soil moisture at the surface of the soil. Air temperature measurements and air pressure measurements were carried out using barometric pressure gauge Diver DI 500, Eijkkelkamp. The chamber's air temperature and air pressure meter was placed in the chamber just before the dome was secured. The measurement time was 400 seconds (Grinfelde *et al.*, 2017; Valujeva *et al.*, 2017). In order to transform the measurement of the concentration of Picarro G2508 into greenhouse gas emissions per hectare, the equation for the ideal gas position was used for the conversion of the emission factor to a concentration per day (Formula 1).

$$F = p \cdot \frac{V}{A} \cdot \frac{\Delta c}{\Delta T} \cdot \frac{273}{T+273}, \text{ where} \quad (1)$$

F – emissions from soil (g ha⁻¹ day⁻¹); p - gas density in mg m⁻³; V – the volume of the chamber in m³; A – camera area m²; Δ c/Δ T – mean change in concentration at ppm s⁻¹; T – camera temperature in °C.

Descriptive statistics, box plots, and the Kruskal-Wallis test have been used for data processing because the data do not correspond to the normal distribution, for data processing (Ruxton & Beauchamp, 2008; Vargha & Delaney, 1998) using XLSTAT software.

Results and Discussion

During the study period, a significant amplitude of GHG emission fluctuations is observed. Table 1 summarises the results of GHG measurements and gives an insight into N₂O, CO₂ and CH₄ statistics. A total of 460 observations were made in 2018, 2019 and 2020. The minimum value of N₂O is -19.5 g ha⁻¹ day⁻¹, maximum of 273.4 g ha⁻¹ day⁻¹. CH₄ has a minimum value of -84.8 g ha⁻¹ day⁻¹, and a maximum of 514.1 g ha⁻¹ day⁻¹. The minimum value of CO₂ is -13.0 g ha⁻¹ day⁻¹, maximum of 1026.7 g ha⁻¹ day⁻¹. The results of all gas emissions measurements show a significant discrepancy between the arithmetic mean and the median values, indicating observed extreme values.

The next step is to analyse the differences in each GHG emission in the context of crops grown. Figure 1 shows the distribution of N₂O emissions depending on the crop. The highest dispersion of N₂O emission is observed from barley-grown soils, but the lowest from the beans. Extreme maximum values affecting the average values of emissions are observed for all crops, as well as extremely negative values for beans, wheat and rapeseed. The highest average N₂O emission is formed by barley, while the lowest is formed by rapeseed. It appears that in the fields where beans were grown, a significant difference in N₂O emissions was observed compared to the fields of rapeseed and barley. There is also a significant difference in N₂O

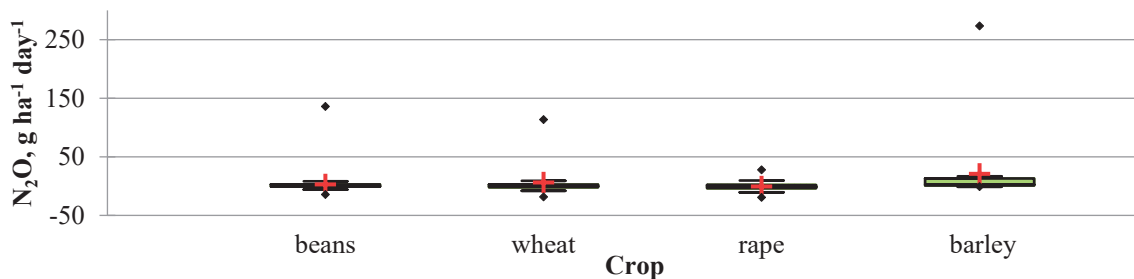


Figure 1. N₂O emissions by crop groups.

Table 2

Multiple pairwise comparisons using the Steel-Dwass-Critchlow-Fligner procedure / Two-tailed test

	N ₂ O, g ha ⁻¹ day ⁻¹ beans	N ₂ O, g ha ⁻¹ day ⁻¹ wheat	N ₂ O, g ha ⁻¹ day ⁻¹ rape	N ₂ O, g ha ⁻¹ day ⁻¹ barley	Groups		
N ₂ O, g ha ⁻¹ day ⁻¹ beans		1.336	5.956	-6.942	A		
N ₂ O, g ha ⁻¹ day ⁻¹ wheat	-1.336		4.766	-6.893		B	
N ₂ O, g ha ⁻¹ day ⁻¹ rape	-5.956	-4.766		-8.756		B	
N ₂ O, g ha ⁻¹ day ⁻¹ barley	6.942	6.893	8.756				C

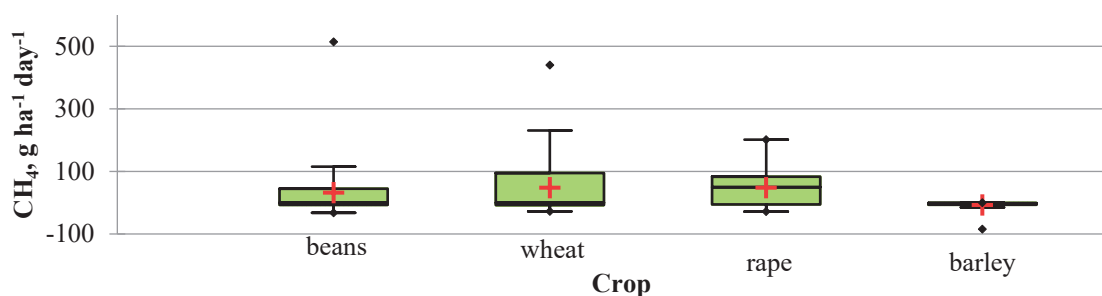


Figure 2. CH₄ emissions of by crop groups.

emissions from wheat fields compared to rapeseed and barley. Barley from the perspective of N₂O, compared to other crops, produces significantly higher emissions, while rape-grown soils emit significantly lower emissions.

The independent samples Kruskal–Wallis test were used to test Null Hypothesis: *The distribution of N₂O emissions is the same for different crops.* As the computed p-value was lower than the significance level alpha=0,05, one should reject the null hypothesis, and accept the alternative hypothesis. The risk to reject the null hypothesis while it is true is lower than 0.01%. Steel-Dwass-Critchlow-Fligner procedure was used to analyse the impact of differences between crops on N₂O emissions (Table 2).

The distribution of CH₄ emissions by crop groups is shown in Figure 2. The largest distribution of CH₄ emissions has been observed from wheat-grown soils,

while the smallest for barley, where extreme negative values have also been observed. Value of CH₄ emissions depending on the crop grown. It appears that the only culture that has a significant impact on CH₄ emissions compared to other crops is barley. In all three options, emissions have decreased. For other crops, the average values of CH₄ do not differ significantly.

The independent samples Kruskal–Wallis test were used to test Null Hypothesis: *The distribution of CH₄ emissions is the same for different crops.* As the computed p-value was lower than the significance level alpha=0.05, one should reject the null hypothesis, and accept the alternative hypothesis. The risk to reject the null hypothesis while it is true is lower than 0.01%. The Steel-Dwass-Critchlow-Fligner procedure was used to analyse the effect of differences between crops on CH₄ emissions (Table 3).

Table 3

Multiple pairwise comparisons using the Steel-Dwass-Critchlow-Fligner procedure / Two-tailed test

	CH ₄ , g ha ⁻¹ day ⁻¹ beans	CH ₄ , g ha ⁻¹ day ⁻¹ wheat	CH ₄ , g ha ⁻¹ day ⁻¹ rape	CH ₄ , g ha ⁻¹ day ⁻¹ barley	Groups		
CH ₄ , g ha ⁻¹ day ⁻¹ beans		-1.375	-3.419	4.580	A		
CH ₄ , g ha ⁻¹ day ⁻¹ wheat	1.375		-1.262	5.037		B	
CH ₄ , g ha ⁻¹ day ⁻¹ rape	3.419	1.262		6.400		B	
CH ₄ , g ha ⁻¹ day ⁻¹ barley	-4.580	-5.037	-6.400				B

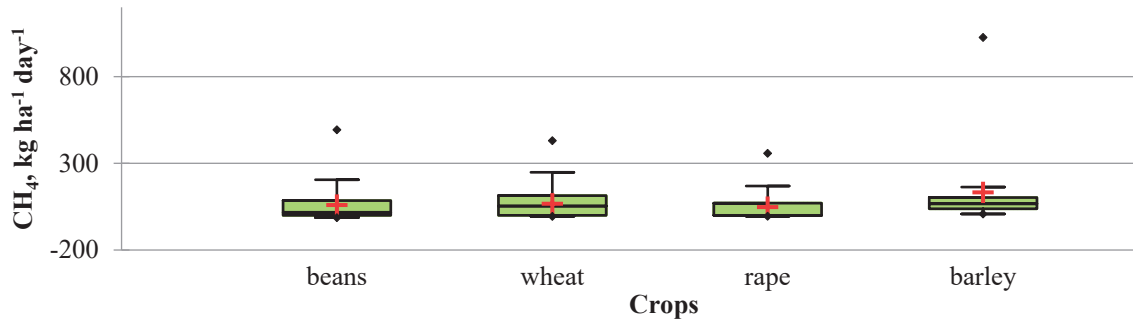


Figure 3. CO₂ emission by crop groups.

Table 4

Multiple pairwise comparisons using the Steel-Dwass-Critchlow-Fligner procedure / Two-tailed test

	CO ₂ , kg ha ⁻¹ day ⁻¹ beans	CO ₂ , kg ha ⁻¹ day ⁻¹ wheat	CO ₂ , kg ha ⁻¹ day ⁻¹ rape	CO ₂ , kg ha ⁻¹ day ⁻¹ barley	Groups	
CO ₂ , kg ha ⁻¹ day ⁻¹ beans		-1.366	1.114	-5.568	A	
CO ₂ , kg ha ⁻¹ day ⁻¹ wheat	1.366		2.172	-3.517	A	
CO ₂ , kg ha ⁻¹ day ⁻¹ rape	-1.114	-2.172		-7.162	A	B
CO ₂ , kg ha ⁻¹ day ⁻¹ barley	5.568	3.517	7.162			B

Figure 3 shows the distribution of CO₂ emissions depending on the crop. Large scatter and extreme values of CO₂ emissions have been observed for all crops. The highest average value was observed from the soils where barley was grown – 307.261 kg ha⁻¹ day⁻¹, while the lowest average value of CO₂ emissions was observed in the rapeseed fields - 205.796 kg ha⁻¹ day⁻¹. There is no significant difference between beans, wheat and rapeseed in the formation of CO₂ emissions. Barley has been reported to produce emissions of 5.568 kg ha⁻¹ day⁻¹ higher than beans and 7.162 g ha⁻¹ day⁻¹ higher than rapeseed with a significant difference.

The independent samples Kruskal–Wallis test were used to test Null Hypothesis: *The distribution of CO₂ emissions is the same for different crops*. As the computed p-value was lower than the significance level alpha=0.05, one should reject the null hypothesis, and accept the alternative hypothesis. The risk to reject the null hypothesis while it is true is lower than 0.01%. Steel-Dwass-Critchlow-Fligner procedure was used to analyse the impact of differences between crops on CO₂ emissions (Table 4).

Conclusions

The results of the three-year studies show a significant variability in GHG emissions, especially the extreme values for N₂O emissions, which reach of 273.4 g ha⁻¹ day⁻¹. Analysing GHG emissions from clay soils by crop groups, the Kruskal-Wallis test shows a statistically significant difference in the effect of cultivated crops on GHG emissions. N₂O emissions showed a statistically significant difference between crop groups. Barley has a significant effect on CH₄ emissions compared to other crops. In future studies, it is necessary to increase the number of plots where measurements are made and the number of measurements by in-depth study of plots where barley is grown. An analysis of the effect of preculture on GHG emissions from clay soils is required.

Acknowledgments

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SUSTAINABLE LANDFILL FINE FRACTION OF WASTE REUSE OPPORTUNITIES IN COVERING LAYER DEVELOPMENT

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Abstract

Resources are lost in dumps from the time civilization knows itself. Solid waste handling through 'zero waste' concept is important for disposed waste reuse/recycling. The challenge for future is landfill mining (LFM) – one of the approaches dealing with that approach. We can think of recycling of valuable components such as plastic, metals and even rare soil elements if we have the right technology. Fine fraction of waste derived from excavated, separated and screened waste is also a perspective of circular economy as this inert fraction may serve as methane degradation layer for covering the old as well as new landfills. It may reduce harmful CH₄ emissions and diminish the raw material use for closure of dumping sites. The aim of this study is to give an outlook on opportunities and describe other benefits for circular economy from innovative construction technology of cover layer.

Rejected material may contain up to 40–60% of dump site/landfill mass and we may have interest in: 1) estimation of fine fraction of waste as functional construction material; 2) watching environmental effects – possible leaching and emissions; 3) keeping dumpsite revitalization as the master plan idea. First studies revealed the potential of fine fraction of dumpsite material for sustainable covering layer development. This study is supported by the project No.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'.

Key words: landfill biocover, fine fraction of solid waste, circular economy, landfill revitalization.

Introduction

Landfills and environmental concerns have been studied widely (Burlakovs *et al.*, 2013; Critto *et al.*, 2006; Prokop, Schamann, & Edelgaard, 2000). Studies about monitoring, leachate, opportunities of recycling, etc. are of critical importance (Burlakovs, Kasparinskis, & Klavins, 2012). Innovative technologies of research and applied action are needed to break the vicious cycle of burying the waste without interest on reuse/recycle of valuables as well as diminishing landfill gas emissions (Burlakovs *et al.*, 2014, 2017, 2019).

In the context of landfill mining prospection and exploration, activities are performed to locate landfills, estimate their dimensions and characterise the material quantities and qualities. In this way, data for a feasibility study are obtained. The importance of proper exploration in the early stages of a possible landfill mining project has been highlighted by Hull *et al.* (2005), Goeschl (2010) and Burlakovs *et al.* (2015).

The aim of this study is to give an outlook on opportunities and describe other benefits for circular economy from innovative construction technology of cover layer. Landfills pose serious environmental threats if not closed and revitalized property; moreover, we have to deal with harmful greenhouse gasses such as methane (Burlakovs 2008, 2012; Ozola *et al.*, 2019; Pehme *et al.*, 2020). Innovative solutions for hydrological improvements and diminishing

of leachate contaminants, including nutrients and dissolved organics are of high importance (Tamm *et al.*, 2008; Saaremäe *et al.*, 2014; Pehme *et al.*, 2019).

The problematics of the process also includes the necessity of revitalization of the dump site so the site in some occasions may be useful as the industrial, commercial or even green area after the completion of remediation (Hogland *et al.*, 2018; Pehme *et al.*, 2018; Valujeva *et al.*, 2018).

Sampling and sensing aim at producing a model of the reality. Techniques which can support this process are image processing methods, geostatistical modelling and prediction, reconstruction of stratigraphy and layered build-up. The material characterisation is crucial, yet still in a very early stage of development. The combination of several sensing techniques should offer a potential to solve this process (Burlakovs, Kriipsalu *et al.*, 2013). The quality of LFM material determines the recycling opportunities and the choice of a processing technology. The combination of these methods can also be used for the products of valorisation technologies to quantify the value added due to processing (Burlakovs *et al.*, 2016).

For ex-situ LFM, there are a number of separation challenges which are not as significant in typical waste processing set-ups. The high proportion of soil material means that a relatively low percentage (compared to untreated household waste) of the excavated material is available for recycling or energy recovery. Quaghebeur *et al.* (2013) reported that almost 50%

of excavated waste was soil-like material. In other LFM projects this number is even higher, in Maul *et al.* (2014) found that up to 70% is fine fraction (<60 mm). The machinery in sorting plants is applicable for LFM, but the fine fraction treatment part of the plant will face overloading issues. When considering the feeding of these kinds of plants with a screw feeding device, the high amount of soil-like fines will lead to technical problems. The feeder will face clogging issues and therefore a steady-going feeding is difficult to accomplish. As suggested by Quaghebeur *et al.* (2013), when the organic components are removed, the remaining material might be recycled as filler in concrete or other construction materials (e.g. in mortars if particle size is below 2 mm). However, the quality of the soil-type waste may not always be suitable for recovery because of elevated metal concentration (Cd, Cr, Cu, Ni, Pb and Zn), especially in the fine fraction of inert waste. This last type of waste should preferably be reused in different products and one of them is the functional construction material as the covering layer for the closure of the landfills.

Materials and Methods

The excavation and separation techniques in landfill mining

Excavation techniques, both continuous and discontinuous systems, in landfill mining can be similar to those applied in surface mining. Site location, landfill volume and geometry, physical and chemical properties of waste materials and their spatial location will affect the applicability of the adequate mining method and system. Geometrical characteristics can define the sequence of mining, in strips, terraces or in a traditional cone-shaped excavation. The excavation geometry or layout has to consider the accommodation of the main equipment and their operations, namely benches, haul roads, overburden and waste disposal sites. Other aspects

like transport distances and environmental restrictions (Geysen, 2013) will also influence the methodology.

The removal of waste material from a disposal site may require the use of heavy mining equipment. This equipment is the same type of equipment that might be seen at road building projects, including backhoes, bulldozers, and front loaders (Burlakovs & Vircavs, 2011; Jain *et al.*, 2014). Excavation and especially waste transport create traffic, which, consequently, creates emissions such as e.g. dust in dry climate conditions. On certain sites, custom-designed equipment may be used to prevent the spread of contaminated waste and protect the health of workers and nearby populations.

Excavation using other mixed or continuous systems can minimize or eliminate CO₂ emissions, dust, noise and vibrations due to the replacement of diesel engines of heavy machines by electric equipment (continuous mechanical excavators, road headers, draglines, bucket wheel excavators, scrapers and belt conveyors). These systems, when properly designed and adapted to landfill mining, can have some environmental advantages to the operation of excavation. Continuous excavator machines are mobile and perform several operations at a time: excavation, loading and transport to other devices like belt conveyors and can be remotely controlled (Figure 1).

The usage of excavators to remove waste material and/or final and intermediate cover layers from the landfill body is a commonly applied method in the landfill mining context. In general, there are two methods (Figure 2) for excavating landfills (Goeschl, 2010):

- Excavating from the top of the landfill with an excavator in approx. 3 meter levels;
- Excavating from the bottom with a front loader beginning with the removal of thinner layers.

In practice, excavating from the top has been found to be the most effective and economical method.

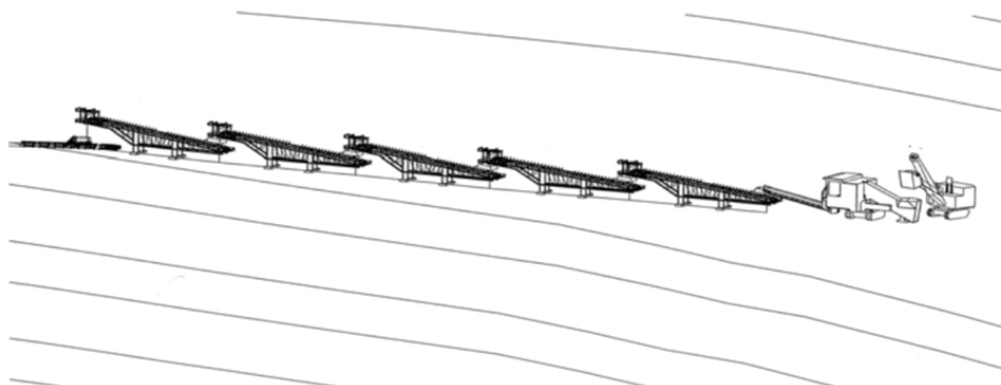


Figure 1. Schematic view of continuous mining equipment.

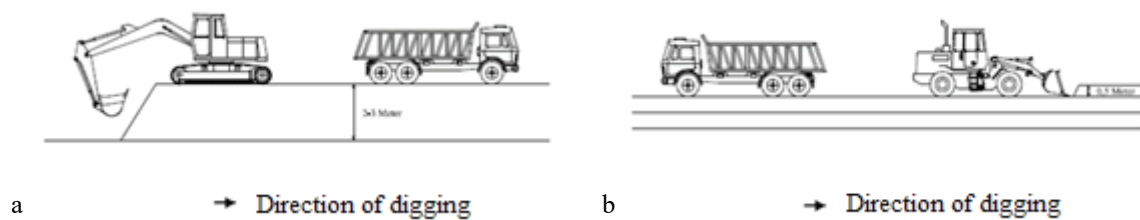


Figure 2. Landfill excavation methods: ^a – digging below ground level;
^b – digging layer by layer (Goeschl, 2010).

When excavating from the top of a landfill in layers, a typical depth for each layer is 2 to 3 metres. The daily volume of excavated waste is usually limited by factors other than the excavator, such as the capacity of the treatment plant. One example of excavated volume from a landfill in the United Arab Emirates showed an average of 1200 m³ waste excavated per each excavator (Goeschl, 2010). In the most typical case, the excavator equipment stands on top of the landfill and moves backwards while excavating. The front loader with thinner layers has been advised to be used mostly for cleaning of the natural soil on landfill bottom layers and in special cases. The cover layer of the landfills is often kept separated from the excavated waste (Jain *et al.*, 2013).

Other excavation methodologies, especially those that use continuous systems, should be encouraged since they have proven their efficacy in mining and construction activities. On the one hand, they allow geotechnical impact mitigation, since the equipment is outside the landfill and far from slopes during excavation. On the other hand, these continuous excavation systems assure vibration absence and eliminate the dangerous weight effect near the slopes.

Leachate, Dust and Environmental Safety

Landfill leachate has been studied in many types of landfills such as municipal solid waste (MSW) (Di Bella *et al.*, 2012), steel slags (Gomes & Ascenço, 2006) and polymetallic sulphide mining wastes (Kontopoulos *et al.*, 1998; Cosme & Gomes, 2004). In these studies, leachate quantity and quality was assessed during different periods of time (Münnich, Bauer, & Frickle, 2012) and experimental works were carried out in order to prevent and mitigate leaching. Besides the traditionally known environmental problems derived from leachate, the nature of landfill materials may also be a concern. Some landfill mining activities such as waste handling, storage, and plant traffic have great potential to produce coarse and fine dust particles that can be harmful for public health. Moreover, depending on waste nature, particulates emitted from landfills may also contain metals such as arsenic, cadmium, chromium, cobalt, copper, lead and manganese. For these reasons, landfill sites require dust monitoring, controlling and suppression

measures to avoid substantial environmental impacts. For many decades dust has been studied as an environmental impact factor by several authors. In the latest years, as a consequence of technological development, the harmful effects of ultrafine particles and nanoparticles on public health have been subject to intensive research. One example is the work published by Gomes *et al.* (2013), where a methodology for monitoring ultrafine particles/nanoparticles in varying environments was evaluated. This approach utilizes online analysers and sampling systems which allow further characterization on collected nanoparticles.

Results and Discussions

Energy issues and functional covering material from fine fraction of waste

Apart from natural and expected variations, it is obvious that inorganic (inert / fine fraction) components always represent a significant portion (> 50wt%) of the mixture. They are formed by the soil fraction used as intermediate/final covers of the landfill and by the inorganic components of the wastes (e.g. from C&D or industrial sludge, etc.). Since Waste-to-Energy (WtE) operations have a crucial role in landfill mining (Bosmans *et al.*, 2013), as a viable alternative to process organic components in the mixture, fine ashes and/or slags are expected to be formed, according to the used combustion technology (Themelis, 2007).

Inorganics tend to be concentrated in the fine fraction (< 10 mm sieve) but coarser particles (e.g. aggregates) are also present (Hogland, 2002; Quaghebeur *et al.*, 2013; Kaartinen *et al.*, 2013). Finding valorisation opportunities for these materials is a challenge, due to their compositional variability and presence of certain undesirable constituents (e.g. chlorides). Most of those components are inert or non-hazardous according to the EN 12457-4 standard (Hogland, 2002; Kaartinen *et al.*, 2013). However, their potential valorisation requires a careful look at the major elements and at certain specific (problematic) constituents, such as chlorides and heavy metals.

In the context of landfill mining or resource recovery from waste, the concept of land asset recovery is not something that contributes to the

application of the technology per se; in fact it is the other way round as the method of resource recovery may impinge upon future use of the land. The design of the waste mining process may take account of this in order to maximise future benefits, as it is this that will govern the site behaviour and condition following processing. The potential for landfill mining is high for developing the covering material / capping to: 1) restore the land; 2) reuse/recycle what possible; 3) real estate aspect use as the benefit.

The purpose of land asset recovery is to ensure that the land itself can be reused in a safe and effective manner, generating revenue where relevant and thus maximising the chance that it can return to productive or beneficial use. It has been noted that landfill redevelopment projects may only be feasible financially if government subsidies are provided (Roccaro, 2013). In such cases, the inclusion of waste mining and resource recovery may increase financial returns and make such redevelopment financially more attractive.

Potential of methane oxidation in covering layer of landfills depends on various factors often studied in applied ongoing closure projects (Pehme *et al.*, 2020). There are still difficulties with quantifying landfill fugitive methane emissions due to the high temporal variability and spatial heterogeneity of emissions. Cost-effective methods for measurements of landfill methane is a challenge to the scientific community.

Examples of low intensity use or light structures are relatively widespread. In particular, the creation of amenity sites such as parkland or sports facilities is well established. A range of examples are provided by the USEPA (1999), including sports pitches and golf courses. Chemlal *et al.* (2013) report a park constructed on a former landfill which required continued groundwater treatment following construction. Ecological restoration is also often considered to be relatively easily constructed, and it is self-maintaining. This is particularly the case if the site is relatively remote from further development and such intensive site use would be inappropriate (USEPA, 1999), but the potential to combine this with recreational use and offer of habitat creation and green space in more urban areas has also been considered. Low maintenance sites such as prairies or grassland are considered (Biederman & Whisenant, 2009) and also have the benefit that they may require relatively little water input, limiting potential water ingress to the waste. Alternatively, there are case studies exploring the potential benefits and problems of greening landfill caps with larger plants such as certain tree species (Hutchings *et al.*, 2001), who found that growth of these more deep-rooted species is perfectly possible if the cap itself is properly designed and constructed to prevent root ingress to the waste. Furthermore,

agricultural uses such as crop growth (Spreull & Cullum, 1987) or cultivation of short-rotation forestry for biofuel generation (Page *et al.*, 2014) have also been considered, but there is relatively little published information available on the success or otherwise of these options.

Creation of structures on closed waste sites is relatively rare due to the long-term issues described above, and because invasive procedures that breach the landfill cap are not desirable. Where they are developed, structures tend to apply relatively little additional loading. Ball, Hill & Morgan (2006) report the development on existing landfills around Northampton, the UK. These old, unlined facilities contain MSW and potentially hazardous materials that are decades old, with inert and construction waste disposed of prior to closure in the 1990s. The redevelopment reported in this study was primarily concerned with lightweight construction and facilities that were relatively unaffected by settlement. Although the waste was old and it was considered that a significant proportion of settlement had already occurred, site uses comprise surface or low rise structures including car parks for adjacent sports stadia and a recycling centre. Wong *et al.* (2013) report settlement monitoring of light redevelopment on landfills in Hong Kong – even the use as a park and recreational area was seen to significantly increase settlement rates. Recently, the possibility of constructing solar energy generation systems on closed waste sites was explored by Sampson (2009). The existence of open space with less likelihood of site development and shadowing from nearby constructions makes such sites particularly suitable. As with any construction, however, the potential for differential settlement exists, which in this case could detrimentally affect foundations and electrical connections as well as cap integrity. Also, solar panels constructed on the slopes of land-raise waste facilities may exacerbate slip failure mechanisms.

Invasive redevelopment of landfill sites offers similar issues to those raised by landfill mining, including health and safety concerns during the process but also the potential for reuse of the materials. Examples of redevelopment in this way are quite rare, but generally take place on waste sites containing relatively inert materials.

Excavated materials are segregated on site, with suitable uncontaminated fill being reused onsite and the remainder taken to another landfill. Information on how the site will be prepared for construction is limited, but as the majority of biodegradable and contaminated material is removed, it is likely to encompass standard ground improvement techniques.

Although waste disposed of in modern facilities is compacted, subsequent changes in the medium to long

term mean that the site will be unsuitable for reuse without some form of treatment. For construction, it would be necessary either to remove the waste entirely, design foundations that avoid using wastes as load-bearing materials (e.g. piled foundations) or invoke some form of treatment process. Any treatment process is likely to require removal of the majority of biodegradable material to ensure that further significant decomposition and settlement are avoided. Mining of waste repositories, particularly *ex situ*, allows this to take place. Remaining inert materials will require ground improvement to provide suitable foundation for future use. Relevant technologies that are already well-established are discussed in some detail by Summersgill and Witherington (2008). Cover systems (i.e. capping) are a straightforward method of protecting against contamination pathways to receptors at the ground surface, similar to a landfill cap itself and with similar elements. Our proposal is to construct the functional material that will diminish the leachate contamination as well as degrade greenhouse gas.

The cover system method is useful with large areas of contamination, which it can treat with the minimum of intervention. Capping does not treat contamination - it remains on site with the potential to cause future harm. This technique is not contaminant-specific as it is simply an inert/ mixed with some organics barrier. However, there may be concern where volatile contamination is present, unless a low permeability cover is used. If there is the possibility of risk from below-ground transport of contamination, then other techniques should be considered, either instead of

or in conjunction with a cover that is used from the landfill inert material *per sei*.

Conclusions

The landfill closure process is not innovative when state-of-the-art is applied; however, novelty might be found out when landfill mining is proposed with inert material redevelopment as the functional covering material. It provides opportunity to reduce the raw material used conventionally as well as reduce greenhouse gasses while destroying them. Pollutant geochemistry and applied engineering are the key spheres when decision to develop such covering material appears. Innovative closure of landfills by capping with fine fraction of waste mixed with distinct amount of soil organics is the future of many revitalization projects. Research is continued and overall guidelines of applied approach are dependent not only on scientific approach but also on site geography and legislative aspects.

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HOW TO CHOOSE OPTIMAL LOCATIONS FOR INSTALLATION OF WIND TURBINES IN RURAL AREAS

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Abstract

To choose optimal place for wind turbine, you need to know two basic parameters: 1. $V_{average}$ – the average wind throughout the year. The total amount of kilowatt hours of electricity you will get depends on this parameter. 2. V_{max} – the maximum possible dangerous gust of wind during a storm. The required strength depends on this parameter and hence also the cost of construction. In order to evaluate the chosen place, it is possible to combine these two parameters to only one physical parameter V_{bojat} . In this article it is called: “Average wind speed which is devaluated by hurricanes” or BOJAT speed.

These measurements must be done for a year or few years in advance. Two devices for such measurements are described in this article: the Anemometer and the Brazmometer. Both are purely mechanical, and that means – they are reliable and cannot lose data because of some electrical shock. Both are made in Latvia. Also, recommendations how to make simple and cheap wooden mast for such measurements in rural area are given.

Key words: Return on investment, wind energy conversion, wind profile, anemometer, brazmometer, wooden tower, wooden mast for wind turbine.

Introduction

The locations for Wind turbine must be chosen correctly; otherwise, it brings only losses. How deep is the problem, can be seen in many publications, for example: Hübner & Michelle, 2019; DW, 2014; Benson, 2021; Weissbach *et al.*, 2014; Kruger, 2018; Joshua, 2018; European Wind Energy Association, 2009. That is why it is necessary to analyse the wind few years before the wind turbine construction.

The two parameters specified in the Abstract have a different effect on the choice of a wind turbine model. These two parameters can be reduced to only one physical parameter: an average speed, discounted by hurricanes. This parameter is introduced here for the first time; let us call it the Bojat Speed, formula 10.

For the final solution of the issue from an economic point of view, it is necessary to take into account other, not only physical, but also purely economic parameters: the price of electricity in the country, the demand for electricity in a given settlement, the average rate of return on investments in the World, the level of inflation, reliability of the equipment supplier, etc. Such an abundance of necessary information confuses decision-makers. One possible option striving to reduce the number of parameters is the usage of ball system (Baseer *et al.*, 2017). But the idea which is proposed here has an advantage of objectivity, because it uses purely physical parameters.

Materials and Methods

The authors have created prototypes of two instruments for measuring these parameters: an anemometer and a brazmometer. The devices are purely mechanical and are cheap.

It makes no sense to buy one expensive electronic anemometer, which records the strength of the

wind every second and transmits data via satellite communication to a computer, but does it only at one location. It is much better for the same money to use dozens of cheap mechanical devices at different locations. No one needs wind speed reports every second. In practice, only two integral figures are needed after a year of observation: the average wind speed and the maximum possible wind speed. But these two numbers must be collected in as many locations as possible.

A farmer who is considering the construction of wind turbine will be able to install several such measurement devices at different ends of his field, and after a year of observation he will be surprised to find that at some location the average wind blows stronger, and dangerous gusts of wind are weaker than elsewhere in the same field. That will give him the opportunity to get benefits from the correct placement of the wind turbine.

The first device is anemometer. It is used to measure average wind speed during a very long period.

The second device is used for measurement maximal possible dangerous wind gusts. We call it “Brazmometer”. – “Brāzma” – gust of wind (Latvian).

The brazmometer records only one figure – the strongest wind which was during long observation – V_{max} .

Usage of Logarithmic scale or Beaufort scale.

Problem: The Force of wind pressure is proportional to the square of Wind Speed.

So, if Wind changes ten times $5 < \text{Wind Speed} < 50 \text{ ms}^{-1}$, then the Force (dynamic pressure) changes hundred times $25 < \text{Force} < 2500$ units.

It is inconvenient to show such a huge range on one single dial. That is why the Logarithmic scale may be more suitable. Alternative and more traditional

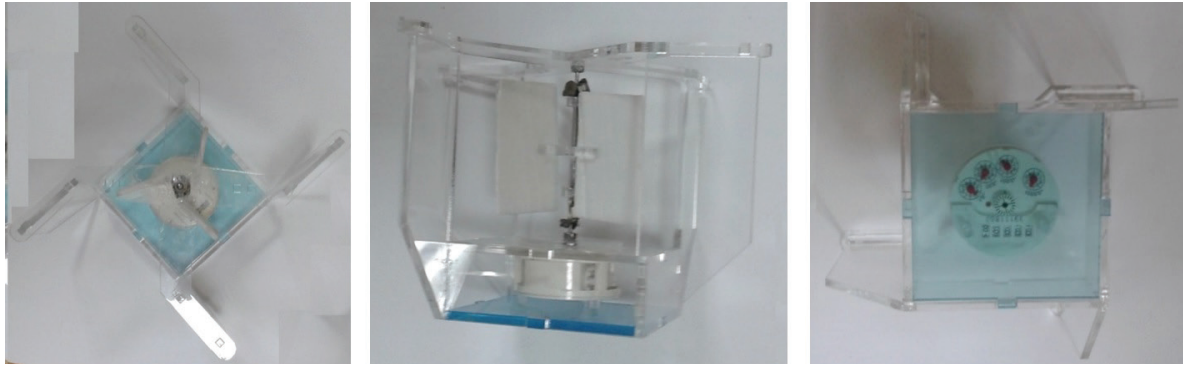


Figure 1. The Anemometer. Photos from different sides. Made in Latvia.

In the end of measurement, you will receive only one figure – the total distance. Dividing it on time you will get the average wind speed – $V_{average}$.

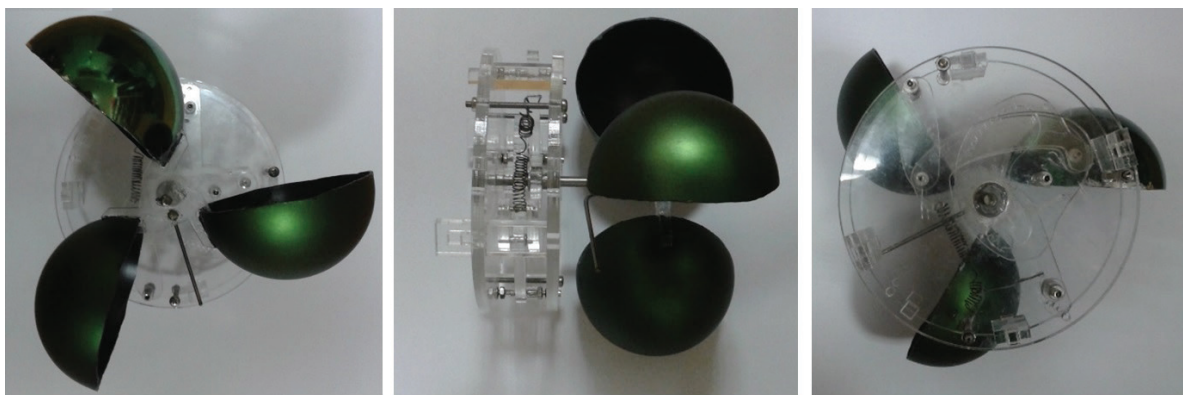


Figure 2. The Brazmometer. Photos from different sides. Made in Latvia.

approach is the usage of Beaufort scale. Defined by following Formula:

$$V = 0.836 * B^{3/2} \text{ m s}^{-1} \quad (2)$$

(“Beaufort Scale”. Encyclopædia Britannica.)

So, B – the Beaufort is cubic root from the force caused by the wind pressure.

To make the angle of rotation of the arrow “Beaufort-dependent” on the force of the wind, a special mechanism was invented. This technical solution is in the process of being patented.

Practical methodological mast in rural area

Although in the future you plan to invest a large sum of money in the construction of a large wind turbine with a mast height of 40 m, but for a preliminary estimation of the wind it is quite possible to use a mast with a height of 10 m.

In rural areas of Latvia, it is easy to find three tree trunks, each 4 – 5 m long, which can be overlapped and tied together with a wire or strong rope to form a 10 m mast. At the bottom, the mast may have a diameter of about 5 – 8 cm, and at the top, about 1 cm. At the top, a 1-m-bar must be nailed horizontally to

the ends of which an anemometer and a brazmometer are attached.

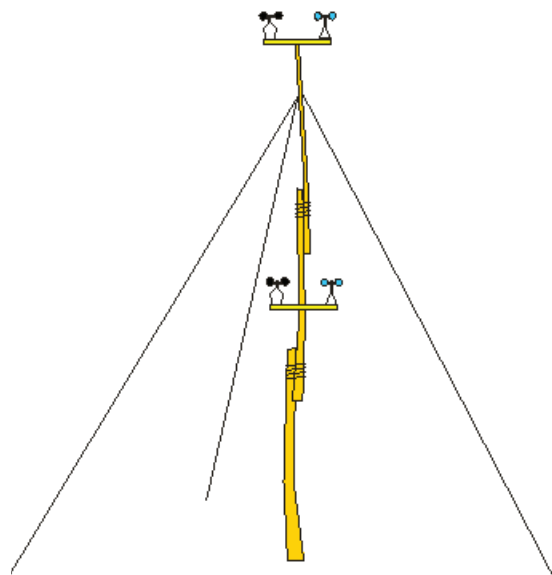


Figure 4. The cheap meteorological wooden mast in rural area with 3 stretched stabilising ropes.

Such a mast does not need to be dug into the ground. It is much easier to reinforce it by making three ropes on different sides that are tied to three heavy anchors in the ground. Lot of advices how to build the mast are here (Geoff, 2013; Freere, 2004; Webb, 2007; Woofenden, 2009).

Any experienced farmer can make it on his own. However, calibrated devices must be purchased. This small investment will help you to avoid making big mistakes when planning a large and powerful wind turbine.

How to calculate wind at 40 m (for example) using information taken from 10 m mast?

It will cost hundreds of times more to build a 40 m mast than a 10 m mast. Estimation about dependence between height and cost are here (Vorohobovs, 2019). Therefore, it is advisable to start with a smaller mast for the preliminary study. Good example is here (Tore, 1999).

At a height of 5 m, a second horizontal bar should be nailed, and two more devices installed on it. This helps to understand how the wind increases with height. This will allow you to roughly calculate the average and maximum speeds at bigger height, for example at 40 m, measuring speeds only at 5 m and 10 m. Just use a formula for the distribution of wind by height.

$$\frac{V_z}{V_{10}} = \left(\frac{z}{10}\right)^\alpha \quad (3)$$

Where V_{10} – is the speed at height 10 m, V_z is wind speed at height Z m, and α – is some coefficient which can be from 0.1 to 0.4 depending from local meteorological peculiarities. This formula can be found here: (Justus, 1976) and here (Emeis, 2001). Many other models are listed in (Archer, 2005).

This formula works both for average wind speed and for maximal wind speeds, but different coefficients α can occur in different locations.

So the α -need is to be calculated first. To do so, it is needed to measure the speeds V_5 and V_{10} at two heights 5 and 10 m, and calculate it by formula:

$$\alpha = \frac{\text{Log}(V_{10}/V_5)}{\text{Log}\left(\frac{10}{5}\right)} = 3.32 * \text{Log}(V_{10}/V_5) \quad (4)$$

and then knowing α it is possible to calculate prognoses for V_{40} using formula (3).

Dependence between average speed and average power

The power produced by the wind generator is proportional to the cube of the wind speed. Therefore, the average wind speed is not exactly the parameter that is responsible for the power produced. However, it is known from practice (Lilienthal, 2021) that the speed distribution obeys approximately the Weibull distribution, which is the same in all countries and continents.

$$f(V) = \frac{K}{A} \left(\frac{V}{A}\right)^{K-1} \exp\left(-\left(\frac{V}{A}\right)^K\right) \quad (6)$$

This probability distribution in this formulae is already normalized. Here A is the Weibull scale parameter in m s^{-1} ; a measure for the characteristic wind speed of the distribution. A is proportional to the mean wind speed $V_{average}$. The coefficient of proportionality slightly depends from K but approximately $A=1.13 * V_{average}$ and K is the Weibull form parameter. It specifies the shape of a Weibull distribution.

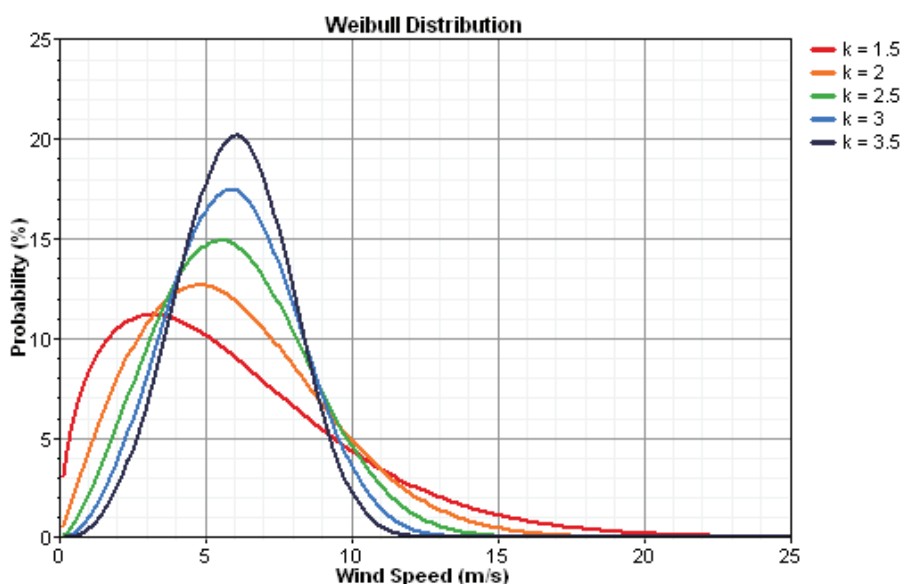


Figure 4. Wind speed distribution for different K (Lilienthal, 2021).

The total reading of anemometer will be proportional to the value:

$$\text{Average}(V) = \int_0^{\infty} V * f(V)dV \quad (7)$$

At the same time, the mean wind power density will be proportional to the value:

$$\text{Average}(V^3) = \int_0^{\infty} V^3 * f(V)dV \quad (8)$$

To estimate the relationships of these two kinds of averaging, some mathematical work is needed. Let us compare the result for three possible values of coefficient K :

$$\text{Average}(V) = 0.716 * (\text{Average}(V^3))^{\frac{1}{3}}$$

at $K=1.5$

$$\text{Average}(V) = 0.806 * (\text{Average}(V^3))^{\frac{1}{3}}$$

at $K=2.0$

$$\text{Average}(V) = 0.859 * (\text{Average}(V^3))^{\frac{1}{3}}$$

at $K=2.5$

(Easiest way to calculate these coefficients is to use Wolfram Alfa computational intelligence).

According to Lilienthal, 2021, in majority of locations $1.8 < K < 2.2$ and never goes beyond the interval $1.5 < K < 2.5$.

This experimental observation makes it possible to compare the average wind speed and cubic root from the cubic average wind speed. Roughly all three above mentioned formulae can be written as:

$$\text{Average}(V) = 0.8 * (\text{Average}(V^3))^{\frac{1}{3}} \quad (9)$$

$\pm 5\%$ possible mistake.

That means, that instead of the hard-measurable average cubic wind speed responsible for mean power, it is possible to use the mean wind speed easy measureable by a simple anemometer. And then multiply it by a coefficient $1.25 = 1/0.8$ and raise it to the third power.

However, it should be understood that such a simple pattern does not apply to dangerous gusts of wind. The fact is that dangerous gusts of wind occur only during hurricanes. And hurricanes come from far away. They are formed thousands kilometres away above the oceans, and the local topography does not affect on them as strong as it affects on the mean wind. Of course, some dependence between two kinds of averaging still exists, but it makes no sense to analyse it because during hurricanes the wind turbines do not function.

Therefore, hurricane statistics should be kept separately and not squeezed into the tail of the general Weibull distribution.

Results and Discussion

Economical aspect and the idea of mean wind speed which is devaluated by hurricanes (Name proposed: "Bojat wind speed")

A wind generator has its own cost, which is an investment. The cost price is proportional to the weight of materials spent on construction. And the weight of the materials used is proportional to the required strength. The dangerous breaking pressure that some gust of wind can exert is proportional to the square of the wind speed V . Information about hurricanes can be taken from different methodological sources, for example Brooks, 2003.

Therefore, it can be argued that the cost of building a generator is proportional to the square of the maximum possible speed of a gust of wind in a given location.

On the other hand, it can be considered that the income received is proportional to the power of the wind generator, which is proportional to the average cube of wind speed.

Therefore, the income from investments in wind energy will be proportional to one physical parameter:

$$V_{bojat} = \frac{V_{average}^3}{V_{max}^2} \quad (10)$$

Where: $V_{average}$ – is the mean wind throughout the year, V_{max} – the maximum possible dangerous gust of wind during a storm. V_{bojat} – is one integrated parameter which helps to evaluate suitability of the place for wind power.

V_{bojat} is nothing else but some effective speed measured in meters per second. The name is suggested: Average wind speed devaluated by hurricanes or the Bojat Speed from Latvian language Bojats (Spoiled, Devaluated). It will always be significantly less than the real average wind speed.

For economic calculations and for making final decision to build or not to build a wind turbine, it should be multiplied by all kinds of economic coefficients such as the cost of electricity, profitability of a bank loan, demand for electricity and so on, like it is done here (Garrad, 2021). But this is not the purpose of this article which is limited only to physics.

Information on the average wind speed devaluated by hurricanes (the Bojat speed) is a basic physical parameter for wind energy projects and should be measured before any consideration of future construction begins.

From two places, the one with the best V_{bojat} parameter should always be chosen.

Unfortunately, till now only maps for the mean wind are available in the Internet. This leads to erroneous conclusions, for example:

Looking at these maps, you might think that Latvia and Mexico have roughly the same opportunities for

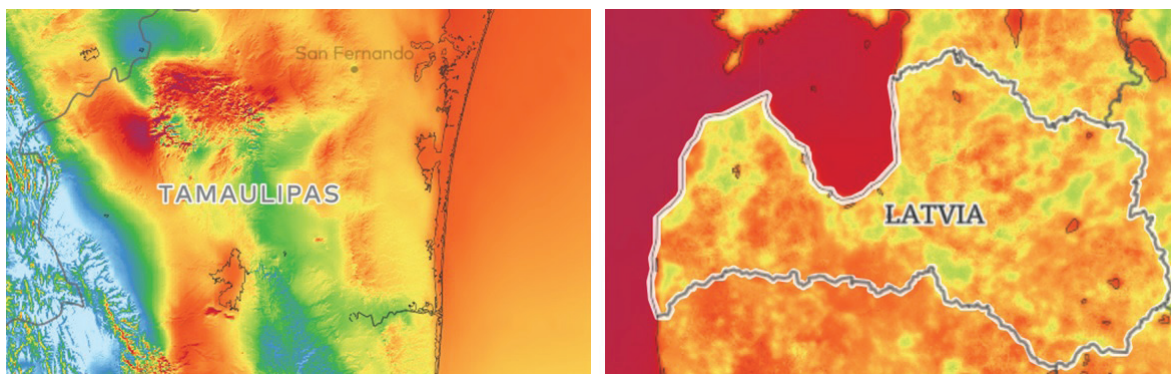


Figure 7. Average wind speed. Mexico Tamaulipas (left), Latvia (right).

Source:(Global wind atlas).

wind energy development, because both have areas which are marked with brown colour which symbolizes average wind speed $V_{avarage} = 8 \text{ ms}^{-1}$. But it is an incorrect conclusion. In Mexico, in 2015 was Hurricane Patricia, when the wind achieved its record peak intensity with maximum wind gust of $V_{max} = 96 \text{ m s}^{-1}$ (Todd, 2016). On the other hand, for Latvia the maximum wind gust was in 1967, $V_{max} = 48 \text{ m s}^{-1}$. (Latvijas vide ģeoloģijas un meteoroloģijas centrs).

Using formulae above, we can calculate: $V_{bojat} = 0.055 \text{ m s}^{-1}$ for Mexico and $V_{bojat} = 0.22 \text{ m s}^{-1}$ for Latvia.

So Latvia has the areas which are 4 times more profitable for wind energy than Mexico does! Not because the mean wind is stronger, but just because there is no need to make the Latvian wind turbines as hurricane-proof as in Mexico, and that is why they can be made 4 times cheaper.

Conclusions

The article introduces a new integral physical parameter – the BOJAT SPEED that allows you to compare the suitability of different places for installing the wind turbines.

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This single parameter is the combination of two other physical parameters – average wind speed and maximum wind speed during a hurricane ...

The article describes the prototypes of two devices for measuring the average wind speed and maximum wind speeds that were created in Latvia. Thus, using these devices and having received these two digits, it is eventually possible to calculate one single digit for each given specific location.

Now the procedure is clear. Every farmer can do it: just make such measurements in several places and calculate the BOJAT SPEED for each place, then the exact place where this parameter will be biggest, will be the best place for installation the wind turbine. The Bojat speed is more informative than Classes of Wind power density which are traditionally used, for example here (Global wind atlas, 2021).

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INFLUENCE OF BIOLOGICAL ADDITIVES ON SOIL MOISTURE DYNAMICS IN THE CONTEXT OF CLIMATE CHANGE

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Abstract

In recent years, climate change trends specific to the world's regions have been observed in Lithuania. Droughts and torrential rains are increasingly being recorded, causing long-term waterlogging. As Lithuania is an agrarian country, the horticulture sector is developed. Abundant growers of potatoes, cabbage and other vegetables are counted in years. It is estimated that the consumption of potatoes in Lithuania is more than 96 kg per capita per year. However, potatoes, which are grown by the majority of crop farms, suffer most from frequent natural droughts. To lower droughts influence, farmers can install irrigation systems or use biological additives in the field, such as agropelrite and agроверmiculite. The experiment was conducted at the two experimental farms in Lithuania, growing 'Vineta' potatoes. The aim of the study was to determine the dynamics of soil moisture in May-August, when different amounts (effects of different percentages) of biological additives are added to the soil. In 2020, the amount of precipitation varied during the research period. During the whole period in Pupasodis fields precipitation was 234 mm. During observed period, 77% of all decades were drier than perennials (DNs). In Šilavotas fields, it was found that 351.5 mm of precipitation fell during the observed period, which is 164.3 mm more than in the Pupasodis area. The distance between experiment plots was more than 70 km. The study results show that soil temperature correlates with exponential dependence with precipitation. The correlation coefficient $r = 0.69$, and when assessing the relationship between soil temperature and ambient temperature, a linear dependence and $R = 0.5649$ were found.

Key words: volumetric water content, soil moisture, mineral additives, precipitation.

Introduction

Many authors note that the yield of agricultural crops is greatly influenced by meteorological conditions (Bujauskas, 2001). In Lithuanian soils, crop yields vary greatly due to meteorological factors, the yield is determined by the air temperature and atmospheric precipitation for all decades.

Potato (*Solanum tuberosum* L.) is a traditional, one of the main food products in Lithuania. They are grown by most farmers and consumed more than 96 kg per capita per year (Bujauskas, 2001). Potato is a shallow rooted crop and extremely sensitive to water stress (Jefferies & Heilbronn, 1991; Fabeiro, Martín, & Juan, 2001; Alva, Moore, & Collins, 2012). The deficit of water has great influence on commercial potato production (Bujauskas, 2001). Soil, water and temperature have been shown to be in potato plant growth and tuber production (Epstein, 1966; Singh, 1969; Wang *et al.*, 2005).

In recent years, drought and soaking problems in Lithuania have become more frequent. Potatoes and maize suffer most from natural droughts, as they need moisture most in July and August (Švedas & Antanaitis, 2000). Most researchers say that the highest potato yield can be grown when the soil moisture is 80% of the field moisture capacity (FMC). When the soil is too dry (15–20% FMC) or too moist (up to 90–100% (FMC)), the potato yield is low (Bujauskas, 2001; Ražukas, 2003). For this, it is necessary that the tubers receive at least 5–6 mm of water from the soil moisture resources every day. The main indicator of the onset of irrigation is the dry top layer (up to 6 cm deep) of the soil. Potatoes are planted when the soil

is already warmed to 7–8 °C at a depth of 10 cm and germinated to 6 °C.

In order to avoid droughts, farmers have several options – to install irrigation systems or to use mineral additives in the fields, which help to increase soil moisture and thus reduce the need for irrigation.

Mineral additives potentially influence infiltration rates, density, soil structure, compaction, soil texture, aggregate stability, crust hardness (Helalia & Letey, 1989), and evaporation rates (Teyel & El-Hady, 1981). They increase the water in the soil available to the plant, which prolongs plant survival under water stress (Huttermann, Oriquiriza, & Agaba, 2009; Jobin *et al.*, 2004; Agaba *et al.*, 2011). Mineral additives can hold or accumulate hundreds of times more water than they weigh themselves. Agроверmiculite, agropelrite, and hydrogel are most often used to hold soil moisture in agriculture. Also, they are widely preferred as they encourage faster root development, reduce the risk of damping off, avoid water logging, and provide an optimum balance of air and water. The optimum moisture level can be maintained around the root, and this is a significant advantage over rockwool, which has less capillary action.

All of these benefits lead to increased plant growth. Most of the articles cited here focus on how these additives affect yield, crop quality, and plant engraftment, and only a few analyses additive ability to bind moisture.

The aim of the study was to determine the dynamics of soil moisture in May–August, when different amounts – 0.5 cm, 1 cm and 2 cm of biological additives are added to the soil.

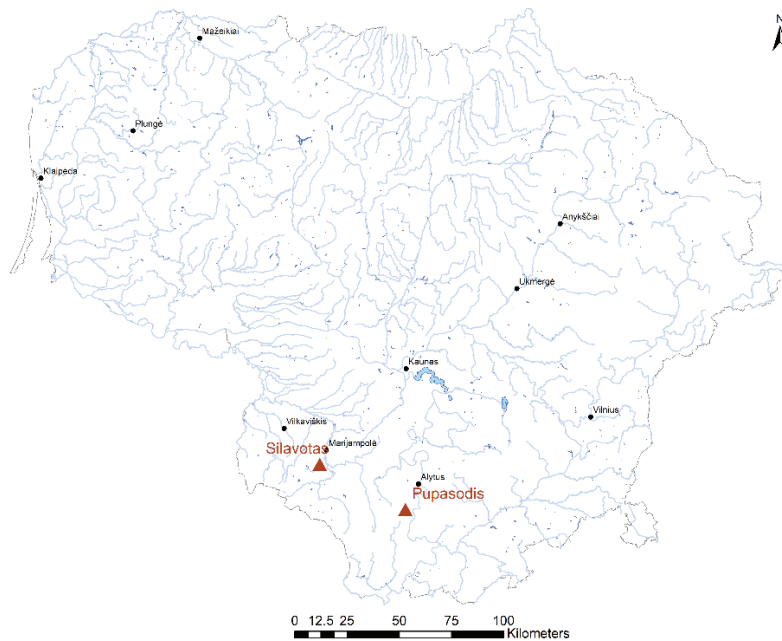


Figure 1. Place of experiment.

Materials and Methods

The experiment was conducted at the two experimental farms in Šilavotas (SF) and in Pupasodis (PF) villages in Lithuania (Figure 1). The aim of the study was to determine the dynamics of soil moisture in May–August, when different amounts (effects of different percentages) of biological additives are added to the soil.

The physical and chemical properties of the soil (Table 1) were determined, samples were taken at a depth of 0–30 cm, the tests were performed in an accredited laboratory.

It was found that at SF study site soil mechanical composition is – loamy sand, and PF study site – sandy. Low acidity or neutral reaction soils (pH 6.5–7.0) are most suitable for potatoes.

In both farms, potatoes were grown in the experimental fields. ‘*Vineta*’ varieties of potatoes

were planted on April 8 in SF and on May 6 in PF. The effectiveness of soil moisture retaining additives was studied by spreading a layer of agroperlite or agrovemiculite of different thickness (0.5 cm – 2%; 1 cm – 4%; 2 cm – 8%, as a volumetric percent of soil) on the soil surface. The Figure 2 shows how the experimental 5-acre area is arranged for different amounts of biological additives.

A ‘TDR 150’ device was used to measure the volume of water (%) in soil, the operation of TDR is based on the measurement of the rate of change of voltage (wave). The voltage is supplied by a wire which enters the measuring probe and is inserted into the soil. The rate of propagation of the voltage pulse in the measuring probe is a dimension that can be interpreted as soil moisture in an appropriate ratio. The smaller the pulse propagation speed, the wetter the soil. Soil moisture measurements were performed

Table 1

Physical and chemical properties of the soil at a 0-30 cm depth on the study sites

Soil property	Units	Value	
		Pupasodis	Šilavotas
Sand	2000–63 μm	90.6 \pm 7.1	93.2 \pm 7.1
Silt	63 – 2 μm	6 \pm 0.5	4 \pm 0.5
Clay	<2%	3.4 \pm 0.3	3 \pm 0.3
ph.	ph 1 mol / KCl suspension	6.2 \pm 0.2	5.3 \pm 0.2
Concentration of mobile phosphorus (P_2O_5)	mg kg^{-1}	334	300
Concentration of mobile potassium (K_2O)	mg kg^{-1}	120	140
Concentration of mobile magnesium (Mg)	mg kg^{-1}	144	150

			Control			
2-3	1-3	0,5-3		2-3	1-3	0,5-3
Agroperlite			Control	Agrovermiculite		
2-2	1-2	0,5-2		2-2	1-2	0,5-2
			Control			
2-1	1-1	0,5-1		2-1	1-1	0,5-1

Figure 2. Scheme of mineral additives ratio in the soil in the experimental field (explanation: 2-1 mean -2 cm of agroperlite 1 repeat, all ratio has 3 repeats).

every 10 days at a depth of 0–20 cm, and soil temperature was also recorded with 3 measurements in each test field.

Meteorological data of the analyzed period were used from the nearest Alytus and Marijampolė meteorological stations.

Results and Discussion

In 2020, the amount of precipitation changed during the research (Figure 3). During the whole period observed in 2020, in the study fields in PF precipitation was 234 mm and on May 2, the most abundant precipitation was recorded – 52.8 mm. During this short observation period, the soil moisture content was at its most optimal for potato germination conditions. During the 1st and 3rd decades of August, 34.7 mm and -21.7 mm of precipitation fell. Over the next 6 decades, less than 10 mm of precipitation was observed per decade. During this observed

period, 77% of all decades were drier than perennials (DNs). Comparing the dynamics of daily average temperatures with the soil temperature that were fixed from the 1st decade of May to the 2nd of August, the soil temperature at the time of measurement (11–12 a.m.) was always at 12–16 degrees higher. Later, this difference became more even, because from the beginning of June the daily temperature did not fall below 20 °C.

Analyzing the amount of precipitation in SF (Figure 4), it was found that 351.5 mm of precipitation fell during the observed period, which is 164.3 mm more than in the PF study fields. The distance between experiment plots is more than 70 km. In the 3rd decade of June, 72.7 mm of precipitation fell. Precipitation was observed below the perennial rates for the 5th observed decade (1st and 3rd decades of May, 2nd and 3rd of July, 2nd of August). It stood out for the 2nd decade of July, then it fell to 1.8 mm of precipitation.

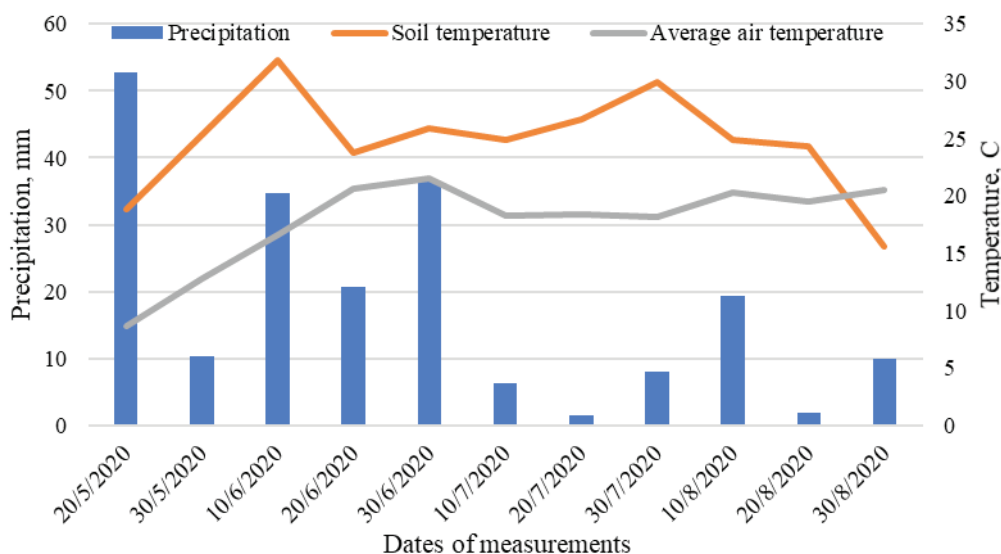


Figure 3. Dynamics of observing meteorological conditions at PF.

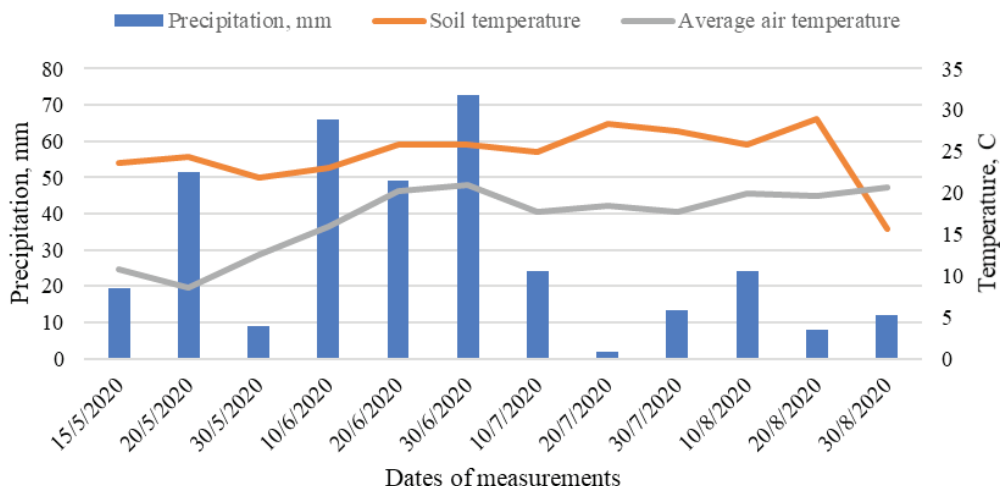


Figure 4. Dynamics of observing meteorological conditions at SF.

Comparing the amounts of precipitation between the two fields, we see that dry and warm weather prevailed in the second half of the vegetation period.

Assessing the dynamics of soil temperature (Figure 3), we observe a tendency that from the 2nd decade of May the soil layer up to 20 cm thick warms up and maintains higher than average daily temperatures

up to 15 °C. In the study fields SF and PF, we see that in the 2nd and 3rd decades of August there is a change between the average ambient temperature. It becomes higher than the soil surface temperature.

Soil moisture measurements were performed at 10-day intervals. In Figure 5, we see that the soil moisture dynamics overlap in the same field of study

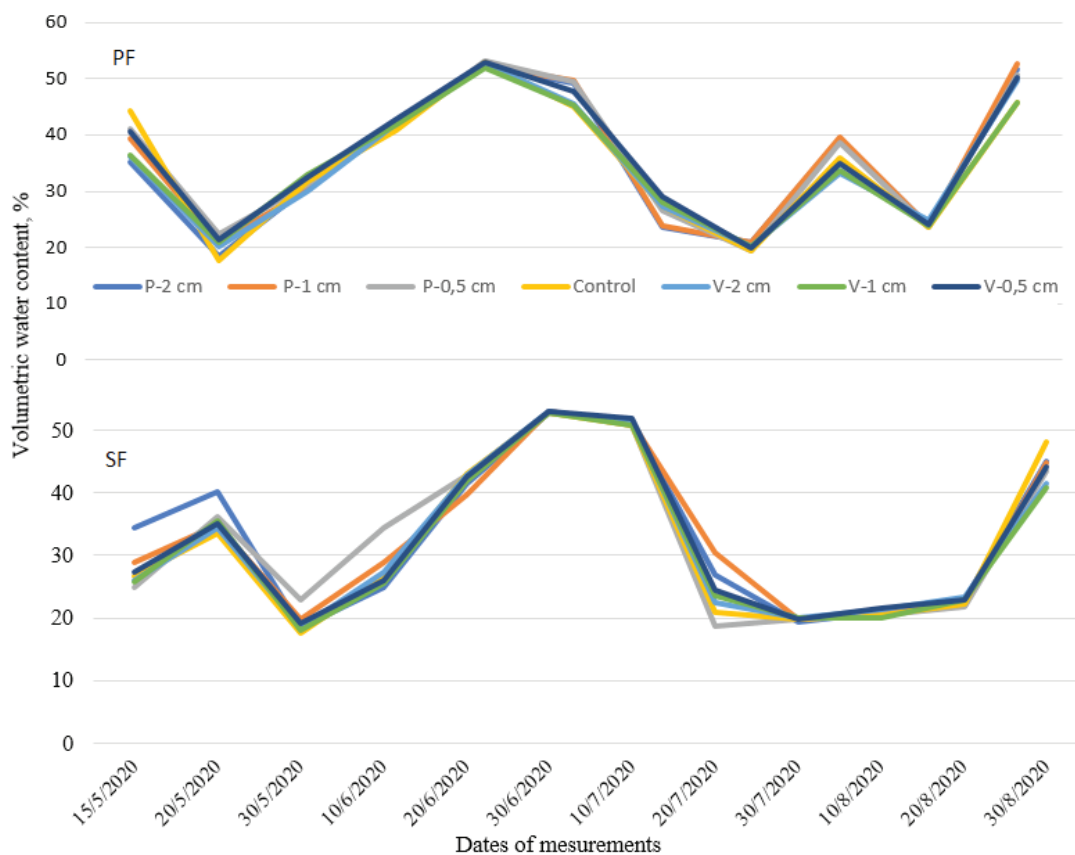


Figure 5. Volumetric soil moisture dynamics in experimental fields.

Table 2

The analysis of volumetric soil moisture

Mineral additives ratio	Average volumetric soil moisture, %		Standard deviation, %		α
	PF	SF	0.05	SF	
P-2cm	35.29	33.22	12.67	12.63	0.05
P-1cm	36.01	32.89	12.63	11.99	
P-0.5cm	36.11	32.43	12.17	12.69	
Control	34.97	31.92	11.82	13.29	
V-2cm	34.71	31.85	11.53	12.38	
V-1cm	34.61	31.48	10.74	12.40	
V-0.5cm	36.00	32.30	11.72	12.53	

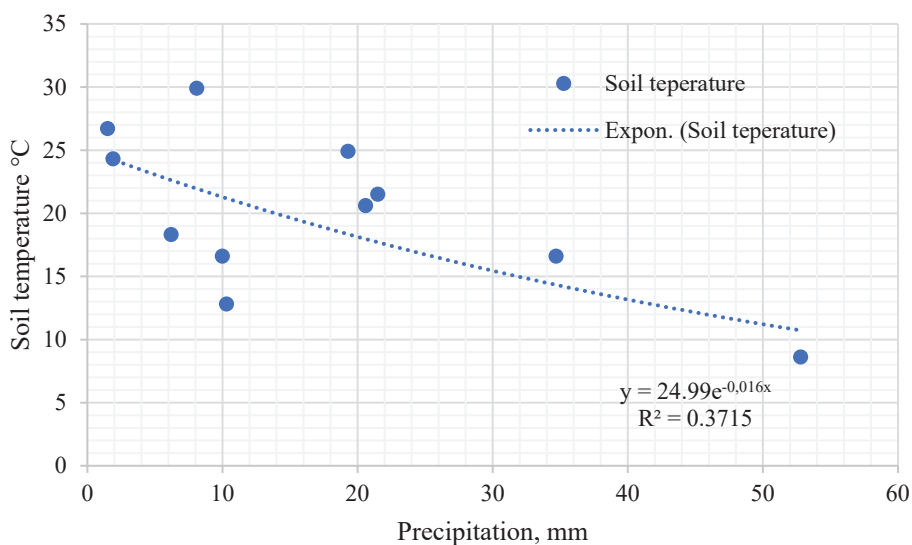


Figure 6. Exponential relationship between soil temperature and precipitation.

even with different rates of biological additives. However, as it might be expected, soil moisture dynamics are mostly influenced by precipitation and air temperature. However, studies performed on PF show that less changes in soil moisture are observed with agrovermiculite than with agroperlite. Agroperlite additives keep soil moisture for longer. In PF fields, during the dry period from the second decade of July till the second decade of August, up to 5% difference in soil moisture dynamics compared to the control fields is observed.

After analyzing the soil moisture dynamics in SF fields, we see that between first and second decades of July, due to high daily average temperatures and low precipitation (25.8 mm), even with the use of biological additives, soil moisture fall could not be stopped. In the control fields it dropped to – 21% (from 51%) and in the fields with 1 cm of agroperlite the soil moisture dropped from 51.1% to 30.4%. However, we record a 10% difference in volumetric water content between the fields, which means that agroperlite spreading it in a 1 cm layer when planting potatoes is able to retain

soil moisture longer. The results presented in Table 2 show that the differences in volumetric water content in the experimental fields range from 2.07% to 3.66%.

As climate change has a major impact on farmers' work schedules, planting and digging deadlines are adjusted. The study found that soil temperature correlates with exponential dependence on precipitation (Figure 6).

The correlation coefficient $r = 0.69$, and when assessing the relationship between soil temperature and ambient temperature, a linear dependence and coefficient of determination $R = 0.5649$ were found, and the correlation between these two environmental phenomena is very strong at $r = 0.751$.

Conclusions

In 2020, the amount of precipitation changed during the research. During the whole period observed in 2020, in the study fields in PF, precipitation was 234 mm. During this period, 77% of all decades were drier than perennials (DNs). In SF, it was found that 351.5 mm of precipitation fell during the observed

period, which is 164.3 mm more than in the PF study fields. The distance between experiment plots was more than 70 km. Comparing the amounts of precipitation between the two fields, dry and warm weather prevailed in the second half of the vegetation period.

Average differences between volumetric water content ranged from 2.07% to 3.66% (to compare all observed data) between Pupasodis and Šilavotas villages experimental fields. A difference of 2.98% was found between the two control fields. The results

explain differences in final amount of production in different regions of Lithuania.

The study found that soil temperature correlates with exponential dependence on precipitation. The correlation coefficient $r = 0.69$, and when assessing the relationship between soil temperature and ambient temperature, a linear dependence and coefficient of determination $R = 0.5649$ were found, and the correlation between these two environmental phenomena is very strong at $r = 0.751$.

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MACHINE LEARNING METHODS FOR CLASSIFICATION OF SENSITIVE DATA

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Abstract

In the era of Big Data there are a lot of new challenges – understanding, processing, and securing the data, assuring data quality, dealing with data growth and other challenges. One of the challenges is to identify and classify data sets in different systems which must follow the conditions defined by different regulations. The classification of these data sets can be automated using machine learning methods. The aim of the research is to provide machine learning methods for classifying sensitive data. The research is based on analysis and comparison of European Union legislation and scientific literature, which addresses issues of data classification using machine learning methods. Special attention is paid to sensitive data defined by the General Data Protection Regulation (GDPR). The main focus in this research is on supervised learning algorithms, where one of the most effective is Naïve Bayes classifier. In order to achieve good results, there is a need to find a proper training data set. Usage of hybrid methods provides a new way for increasing performance of classifiers.

Key words: machine learning methods, classification of data, sensitive data.

Introduction

Data classification is essential to meet compliance standards and maintain control over sensitive data. Machine learning as a subset of artificial intelligence can help to identify and classify data; therefore, an important aspect is to understand the data regulations and rules that are applied for classifying the data.

Sensitive data is a set of special data categories, which must be processed with additional security. These special data categories include religious beliefs, political opinions, racial origin, ethnic origin, as well as membership of professional associations, data about individuals' genetics or biometry and data about sex life and sexual orientation.

Machine learning methods are used in many areas because they have the ability to solve complex issues and even make a prediction. Some of the researchers are working on identifying COVID-19 infection using images of chest X-ray (Sheykhivand *et al.*, 2021). Face recognition (Wang *et al.*, 2019) is also one of the tasks that machine learning can solve.

When it comes to classification of text, many of the researchers are trying to identify the hate speech in social networks. In one of such studies Wiedemann, Ruppert & Biemann (2019) developed an architecture of neural network for recognizing the hate speech. Some other related studies (Doostmohammadi, Sameti, & Saffar, 2019) involve subtasks: first task is to identify if the tweet is offensive or not, the other task is to determine whether the tweet is targeted and the last task is to determine to whom it is addressed.

The aim of the research is to provide machine learning methods for classifying defined by general data protection regulation.

Materials and Methods

This research contains analysis and comparison of European Union legislation, scientific literature

related to sensitive data and machine learning for its classification. The types of machine learning are reviewed, and the Naïve Bayes classifier is explained on a simple example for identifying and classifying sensitive data.

Results and Discussions

The latest law in area of data protection is the GDPR – General Data Protection Regulation (European Parliament and Council, 2016), which within the European Union (EU) came into force on 25 May 2018. It is a huge step forward of achieving wider and more far-reaching protection of any individuals' personal data (Crutzen, Ygram Peters & Mondschein, 2019). The Regulation 2016/679 known also as GDPR, replaces the Data Protection Directive (DPD) 95/46/EC (European Parliament and Council, 1995) and Data Protection Act (DPA) 1998 (Parliament of the United Kingdom, 1998). It applies when personal data is being processed. The GDPR applies to any organization operating within the EU as well as any other organization outside the EU, but which offers services to customers or businesses in the EU. It means that almost any major corporation in the world is affected by GDPR and needs appropriate strategy. The Table 1 highlights some of the differences of definitions for private and sensitive data.

Companies that collect, use, or store personal data related to persons within the EU, must be compliant with the GDPR's privacy and security requirements or face large fines.

'Personal data' is a piece of information which relates to any person – either it's identified or identifiable. It is possible to identify the identifiable person in two ways – directly and indirectly, especially when using an identifier. In this case, as identifier can be used person's name, location data, an identification number, also one or many factors specific to the

Table 1

Difference between Data Protection Act (DPA) and General Data Protection Regulation (GDPR)

Type of data	DPA	GDPR
Personal data	Data related to a person who can be identified by data controller using its possessed data or other information	Any information from which it is possible to identify or potentially identify person.
Sensitive data	Personal data is considered sensitive in case of revealing: a) the racial or ethnic origin of the data subject, b) person’s political opinions, c) beliefs of religion or beliefs like this, d) information about being a member of a trade union, e) conditions of person’s physical and mental health, f) information about person’s sexual life, g) the commission or possible commission by person of any offence, h) proceedings for the offense that is committed or possible offense	Data that have to be protected against authorized access, typically it consists of personal data revealing racial or ethnic origin, person’s opinions about religion, politics, philosophical beliefs, or membership of professional associations, data about individual’s genetics or biometry data, data containing information about persons health condition, sex life or sexual orientation
Processing of sensitive data	Special rules apply, but no special prohibition.	In addition to DPA conditions, the GDPR has few more, where at least one from all conditions must be satisfied: a) the condition about carrying out the obligations under employment has been expanded on the wording related to compliance with additions in obligations under collective agreement, social protection law or social security; b) the condition about establishing and exercising and defencing of legal claims was supplemented by wording in regards to data processing by courts that acts inside their juridical capacity c) the condition related to public interests inside the area of public health has been updated by providing a legal basis for regulatory uses of health data and by sharing health related data with providers of social care; d) new condition is added in addition to DPA which states that processing of sensitive data can also be performed for the purpose of archiving in the public interest, as well as the for research and statistics according to Article 89 (1).

genetic, mental, cultural, economic, physical, cultural or social identity of particular natural person.

The compliance with the GDPR means adopting internal processes to the requirements of regulation. It also means implementing data anonymization, minimization, classification, and other processes. To do a data classification, one should understand the data. However, the definitions of different data classification levels might differ between countries and districts.

The EU Data Protection Working Party during November 2014 published the main criteria that needs to be taken into account, when evaluating the requests for deletion, where the most important decision is about whether the personal data can be considered as sensitive (Li & Saxunova, 2020).

Figure 1 illustrates how the concepts of different types of personal data are related to each other. This

classic relationship shows that some of the sensitive data overlaps with private data and its characteristics; therefore, it can be called private-sensitive data.

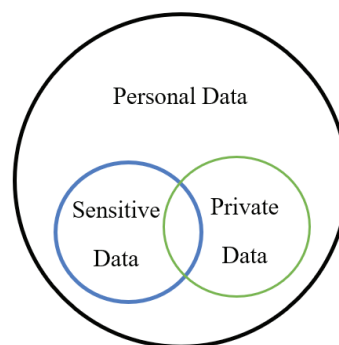


Figure 1. Classic relationship between Personal and Sensitive data.

Table 2

Data anonymization techniques
(Created by the authors based on Personal Data Protection Commission Singapore (2018)
and Victor & Lopez (2020))

Techniques	Description
Attribute Suppression	The strongest technique of data anonymization, because an entire part of data is being deleted or a column is being removed from a dataset.
Record Suppression	Similar to attribute suppression, but more concrete – only specific records are deleted from a dataset.
Character Masking	Withing this technique the data is being hidden by altering its original values. Replacement is usually done by using symbols.
Pseudonymization	This technique makes data less accessible, but it does not fully remove the data and the individual still can be identified by using some additional or indirect information.
Generalization	This technique is known also as recoding – it removes a part of data, thus making the data values less precise.
Swapping	This technique is known as permutation or shuffling – the original data values are rearranged in order to keep the individual values inside the dataset but pointing them to non-original record.
Data Perturbation	The original values are slightly modified – rounding the numbers or by adding some random noise to original value.
Synthetic Data Generation	The synthetic (fake or artificial) data is generated by algorithms rather than by real events.
Data Aggregation	This technique instead of the original data is using its aggregated or average values.

After the GDPR was put into force, most of the companies sent a lot of e-mails to customers explaining the new private policy. The updated policy highlighted the rights to every single person to have the protection of its personal information and the rights to be forgotten, while the previous version of policy contained hundreds of legislative terminologies.

The process for identification sensitive data in most of cases is still done manually, which means higher cost and more time spent, as well as higher chance for getting errors. Moreover, inside the same organization but different departments, the same data can be classified in different ways, which makes it complicated to understand and process. Protecting user’s sensitive data is a major challenge in many organizations. Recent data related incidents (McCandless, 2021) show that millions of users are affected by different data breaches and hacks. All kind of sectors are affected – academic, finance, gaming, government, military, health, etc. This clearly identifies the importance of data security. The first step in protecting sensitive data is identifying it. Once the data is classified, appropriate processes can be applied. Special routines for data anonymization – either in separate development environment or in general might be needed to implement. Data anonymization is a process where original data is either removed or replaced. Table 2 presents the techniques for data anonymization (Personal Data Protection Commission Singapore, 2018; Victor & Lopez, 2020). In order

to automate the process of data identification and classification, machine learning methods can be used.

There are a lot of researches done on protecting sensitive data (Enck *et al.*, 2010; Rastogi, Chen, & Enck, 2013; Budianto *et al.*, 2014). The researchers also have tried to solve different kind of data classification tasks. Some of the authors have tried to identify, weather the author of a written text is a male or female (Argamon *et al.*, 2003). While many researchers try to solve more modern problems related to social network – identification of hate speech in Twitter and its main target (Ayo *et al.*, 2020; Mulki *et al.*, 2019).

The Figure 2 shows the types of machine learning (Betty Jane & Ganesh, 2019):

- supervised learning,
- unsupervised learning,
- reinforcement learning.

Supervised learning contains two variables – the input (x) and an output (Y). The algorithm is used for the function that maps an input to an output: $Y = f(x)$. The goal is to make a prediction for particular data by approximating the function of mapping until the output variable (Y) can be predicted by input variable (x).

It is called supervised learning because in the same manner as a teacher supervises the learning process, the algorithm is supervised by the training dataset, where input data already has a connection to right answers, in this case – the output data. Based on the answers that are provided, the algorithm keeps

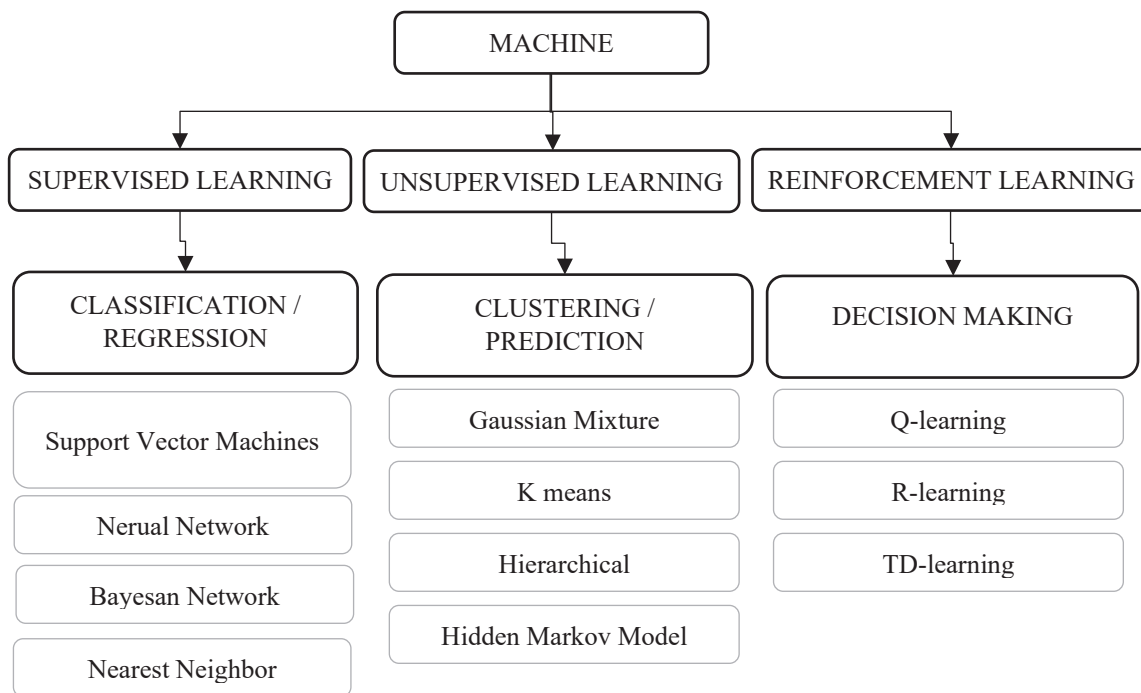


Figure 2. Machine Learning Techniques.
(Created by the authors based on Betty Jane & Ganesh (2019)).

Table 3

Example of training data

Text	Tag	Description
'He believes in God'	Sensitive	Sensitive information about religious belief
'John lives in Paris'	Non sensitive	Personal information about name and location
'Mary has got diabetes'	Sensitive	Personal information about name; Sensitive information that contains health data
Helen believes her soul will be in heaven	Sensitive	Personal information about name; Sensitive information about religious belief
'Her e-mail address is anna88@email.com'	Non sensitive	Personal information about email address;

training by predicting the output, that is corrected by the teacher. The learning process is completed once acceptable level of training results is achieved.

Classification and regression problems are the main subcategories of supervised learning. The problem of classification usually is when the output variable can be defined as a category, such as 'black' and 'white' or 'sensitive' and 'non sensitive'.

The Naïve Bayes classifier is popular and recognized among researchers (Barakaz, Boutkhom. & Moutaouakkil, 2020). This algorithm is mostly used for solving problems of text classification and it is based on a probabilistic classification. It uses joint probabilities of categories and text division into words. Then, the algorithm makes an estimation of the final category where new data should be part of.

In the following example the Naïve Bayes classifier is explained on a simple example for identifying and classifying sensitive data. The data in Table 3 is the training data, where it is already classified in sensitive and non-sensitive data categories. When new data comes, for example 'Eric believes in reincarnation', we would need to classify it and tag if it is sensitive or non-sensitive. In this case, we see that this sentence represents information about person's name ('Eric') and his religious belief ('soul will be in heaven'). From this information we can understand that this information is sensitive, so now we should make sure, that the Naïve Bayes classifier understands the same. Since the Naïve Bayes classifier is a probabilistic classifier, then a probability of sentence 'Eric believes in reincarnation' should be calculated – first assuming that

it contains sensitive data and then that it is non-sensitive information. The higher probability should point to the correct classification. Written mathematically, we want to calculate $P(\text{sensitive} | \text{Eric believes in reincarnation})$ – the probability that the tag of this sentence is Sensitive given that the sentence is ‘Eric believes in reincarnation’. To start building machine learning model, first, it is needed to decide on the features, which are information pieces that are taken from the text and given to the algorithm. For example, in case of sensitive data if we look at health-related data, the features could be person’s gender, age, weight, etc. some of the known information could be also excluded, since it isn’t useful, like person’s favorite color. In a particular case, there are no numeric features, but only the text, which can’t be directly used in calculations. Therefore, word frequencies are used – the order of words and sentence construction is ignored. The features in this case are the counts of each of the words.

Mathematically, the Naïve Bayes’ theorem can be expressed as follows:

$$P(A|B) = \frac{P(B|A)P(A)}{P(B)}$$

In the example we have $P(\text{sensitive} | \text{Eric believes in reincarnation})$. Now, using the theorem we get:

$$P(\text{sensitive} | \text{ericbelievesinreincarnation}) = \frac{P(\text{ericbelievesinreincarnation} | \text{sensitive}) \times P(\text{sensitive})}{P(\text{ericbelievesinreincarnation})}$$

In this case the divisor can be removed, since for the classifier we need to find out the tag with biggest probability. Therefore, we can just compare

$$P(\text{ericbelievesinreincarnation} | \text{sensitive}) \times P(\text{sensitive})$$

with

$$P(\text{ericbelievesinreincarnation} | \text{nonsensitive}) \times P(\text{nonsensitive})$$

The problem is that the sentence ‘Eric believes in reincarnation’ doesn’t appear in our training data, so

we get 0 for the probability both – in sensitive and non-sensitive calculations. In the theory of Naïve Bayes, we assume that each word in the sentence is independent, and we look at each word individually rather than looking at the whole sentence. In other words, our sentence ‘Eric believes in reincarnation’ has the same meaning and sensitivity as ‘in reincarnation believes Eric’ or ‘in Eric reincarnation believes’. Hence, we can write this as:

$$P(\text{ericbelievesinreincarnation}) = P(\text{eric}) \times P(\text{believes}) \times P(\text{in}) \times P(\text{reincarnation})$$

And apply this to what we had before:

$$P(\text{ericbelievesinreincarnation} | \text{sensitive}) = P(\text{eric} | \text{sensitive}) \times P(\text{believes} | \text{sensitive}) \times P(\text{in} | \text{sensitive}) \times P(\text{reincarnation} | \text{sensitive})$$

One problem that appears at this step is that not all words appear in our training data. That leads to incorrect calculations for multiplication of probabilities – if probability of non-existing word is 0, then the multiplication of all probabilities will be 0 as well. To avoid this, we will add +1 to each of every word count from the training data. Hence, if we get a new word, that does not exist in our training data, we will assume, that the count of it is 1. The next steps are just calculations of probabilities. First, we calculate probability of each tag. For a given sentence in the training data, the probability that it is Sensitive $P(\text{Sensitive})$ is 3/5. Next is probability that it is Non sensitive $P(\text{Non sensitive})$, and it is 2/5. Further, we do a calculation based on the counts – in total, there is 21 unique word in our training data (24 non-unique). In order to calculate the probability for ‘believes’ we get:

$$P(\text{believes} | \text{sensitive}) = \frac{2 + 1}{15 + 21}$$

Table 4 shows the probabilities for all words met in sentence ‘Eric believes in reincarnation’ assuming they are sensitive or either non-sensitive.

Table 4

Probabilities for all words met in sentence ‘Eric believes in reincarnation’

Word	P (word sensitive)	P (word non sensitive)
Eric	$\frac{0 + 1}{15 + 21} = 0.027777778$	$\frac{0 + 1}{9 + 21} = 0.033333333$
believes	$\frac{2 + 1}{15 + 21} = 0.083333333$	$\frac{0 + 1}{9 + 21} = 0.033333333$
in	$\frac{2 + 1}{15 + 21} = 0.083333333$	$\frac{1 + 1}{9 + 21} = 0.066666667$
reincarnation	$\frac{0 + 1}{15 + 21} = 0.027777778$	$\frac{0 + 1}{9 + 21} = 0.033333333$

The last step is to multiply all the probabilities met in each tag:

$$P(\text{sensitive}) \times P(\text{eric}|\text{sensitive}) \times \\ \times P(\text{believes}|\text{sensitive}) \times P(\text{in}|\text{sensitive}) \times \\ \times P(\text{reincarnation}|\text{sensitive}) = 0.000003215$$

$$P(\text{nonsensitive}) \times P(\text{eric}|\text{nonsensitive}) \times \\ \times P(\text{believes}|\text{nonsensitive}) \times P(\text{in}|\text{nonsensitive}) \times \\ \times P(\text{reincarnation}|\text{nonsensitive}) = 0.000000988$$

The results show that sentence ‘Eric believes in reincarnation’ is classified as sensitive, because it has higher probability, which is as expected since the test sentence contains information about religious belief.

Conclusions

1. In this research the main focus is on supervised machine learning algorithms. One of the simplest

and most effective is Naïve Bayes classifier. It is fast and produces good results. However, when we talk about sensitive data and data regulations, we might need to look at some other algorithms or a combination of algorithms.

2. An important aspect in machine learning processes is the training data. Some methods might show better results when are trained using one training data set, but the result might become worse, if using other training data. Getting a good training data set for sensitive data is also a challenging task.
3. In order to achieve even better results, the machine learning methods can be used together with other methods – then they become hybrid methods. This concept, where classifiers are combined, provides a new way for increasing performance of the classifiers.

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A STUDY ON LEARNING DIFFICULTIES RELATED TO DYSCALCULIA AND MATHEMATICAL ANXIETY

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Abstract

This article discusses two math learning disorders: dyscalculia and mathematical anxiety. Dyscalculia is a cognitive disorder, math anxiety – emotional. Dyscalculia is a mathematics learning difficulty which is a brain-based condition connected to information organization and proceeding. In turn, mathematical anxiety is one of the emotional factors that causes learning difficulties in mathematics. Therefore, to promote progress in mathematics, the aim of this study is to identify learning difficulties in mathematics from the perspective of teachers and parents, to identify existing experiences in overcoming these learning difficulties in mathematics, and to determine the support needed by teachers. To achieve this goal, both parents and teachers have been surveyed as part of this study. About one-fifth of students have signs of dyscalculia, but 25% – mathematical anxiety. In Latvia, the most problematic type of dyscalculia is the ability to perform mathematical activities and perform both operational and practical calculations, but mathematical anxiety is equally common at all stages of education. According to a survey of teachers, only 7% of students have no mathematics learning difficulties. Parents associate children's learning difficulties with the organization of the learning process (intensive curricula, when the teacher does not have the opportunity to implement a differentiated / individual approach), as well as teachers' attitudes. Research shows that teachers are unable or unaware of how to determine whether a student has dyscalculia or math anxiety and do not have appropriate skills, know-how or training to help a student who experiences learning disabilities and difficulties with mathematics.

Key words: dyscalculia, mathematical anxiety, mathematics learning difficulties, survey.

Introduction

Mathematics is one of the logical and practical academic disciplines to be acquired as a key competence in the context of lifelong learning (EU, 2006, 2018). The importance of mathematics in daily and professional life as well as the fact that level of the mathematical competence influences the quality standards of individual and social life has been proved by several studies. However, learners' knowledge of mathematics is deteriorating year by year and mathematics is one of the reasons for dropping out at all levels of education. For example, in Latvia, based on the data provided by the State Education Content Centre, students demonstrate low result in the centralized mathematics exam every year. In 2016, it was 36.2%, in 2017 – 34.9%, in 2018 – 8.8%, but in 2019 – 32.7%, which is 1.9% points less than in the previous year. The results of 2020 are not taken because the exam was shortened due to the Pandemic. The results often are associated with the laziness, lack of motivation or other circumstances of the learner. However, if a student has not learned something, has not done homework, is not studying, it does not always indicate laziness or unwillingness to do it. In many cases, this indicates that the student is having difficulty learning math and may not be able to learn mathematics.

Mathematics learning difficulties are determined by a number of cognitive and emotional factors. If a student has calculation difficulties, impaired understanding of numerical concepts and mathematical activities, difficulties in understanding and working with numerical information without

words, visually and spatially, often makes calculation errors and has difficulty performing mathematical activities, then this may be a mathematics learning difficulty such as dyscalculia (Rotzer *et al.*, 2009). It should be noted that this is not a disease, but a feature of the pupil's brain that determines the perception and processing of information. However, several studies show that the mathematical performance of a student with dyscalculia is much lower than expected for age, intelligence and education (Büttner & Hasselhorn, 2011).

In turn, mathematical anxiety is one of the emotional factors that causes learning difficulties in mathematics (Dowker, Sarkar, & Looi, 2016). The term 'mathematical anxiety' is described as fear of math or as a negative emotional reaction to mathematics. Several researchers have found that mathematical anxiety can be caused by a number of factors: lack of appropriate mathematical knowledge, learning strategies, application of mathematics in real life, limited exam time, lack of specific materials as well as personality type, lack of confidence, and also stereotypes related to teacher and parent approaches to mathematics (Ashcraft & Ridley, 2005; Finlayson, 2014; Hoffman, 2010; Maloney & Beilock, 2012).

Despite the low achievement of students in mathematics, as evidenced by both the results of the centralized exams and the findings of International Comparative Studies, there is little research on mathematics learning difficulties such as dyscalculia and mathematical anxiety in Latvia. It should be noted that teachers also have insufficient experience in this field and are not familiar with strategies that

can help students develop the necessary mathematics skills.

Studies show that students' mathematical achievement increases when anxiety is controlled (Kamann & Wong, 1993; Maloney & Beilock, 2012), but dyscalculia lasts a lifetime. Of course, performance can improve if intensive developmental action is taken. The student needs to gain an understanding of how to use mathematics in everyday life; parents and teachers need to work together to identify the strategies needed (Turkington & Harris, 2006). Scientists suggest that the link between dyscalculia and/ or mathematical anxiety and performance can be driven. Therefore, to promote progress in mathematics, the aim of this study is to identify learning difficulties in mathematics from the point of view of teachers and parents, to identify existing experiences of overcoming these learning difficulties in mathematics, and to determine the support needed by teachers. To implement this aim, a survey of both parents and teachers has been conducted within the framework of this study.

Materials and Methods

In Latvia, special education specialists have gathered work experience with learners with learning and visual disorders. This material also identifies students' difficulties in learning mathematics (Tübele *et al.*, 2013):

- 1) Insufficient knowledge about the composition of the number, difficulties to learn laws on the formation of numbers;
- 2) Insufficient understanding of positive and negative values;
- 3) Understanding of quantitative (numerical) relations of numbers is not developed;
- 4) Automatically reproduces a sequence of numbers;
- 5) Difficulty in understanding the sequence of information or events;
- 6) Sometimes difficulties in understanding the concepts that apply to such categories such as days, weeks, months, seasons, quarter, etc.;
- 7) Difficulties in determining the relationship of a number to adjacent numbers;
- 8) Difficulties in determining the position of a number in a series of natural numbers;
- 9) Difficulty to perform mathematical operations step by step in a certain order;
- 10) Insufficiently mastered collection of mathematical concepts;
- 11) Incorrect naming of numbers;
- 12) Inaccurate idea of digital graphic structure;
- 13) Elementary method of performing arithmetic operations (child counts on the fingers);
- 14) Does not know addition and subtraction, multiplication and division tables;
- 15) Difficulty in handling money;
- 16) Sometimes difficulty navigating a sheet of paper, writing numbers in columns, navigate long calculations;
- 17) Thinking operations are mostly specific;
- 18) Other difficulties.

To develop the methodology of this study, a study of the scientific literature on dyscalculia and mathematical anxiety was performed, considering the above-mentioned mathematical learning difficulties. In the case of dyscalculia, the symptoms can be very different: very poor mathematical ability, problems in using money, fear of money and transactions with it, unable to fully understand the meaning of numbers and evaluate numerical values, problems with such mathematical activities as addition, subtraction, multiplication and with concepts such as sequence, which can be combined with a poor understanding of directions, inability to read a map, understanding time, time schedule, observance of time, sequence of past and future events (Turkington & Harris, 2006). Dyscalculia is linked to problems representing magnitude of numbers, poor working memory (the ability to hold information in mind whilst performing another task), difficulties with inhibition, poor spatial skills or problems organising sounds (Devine *et al.*, 2017).

As can be seen, several scientists have studied and identified various signs of dyscalculia. Dyscalculia is a specific learning disability in mathematics: difficulty to understanding number-related concepts or using symbols or functions needed for achievement in mathematics, difficulty with the mechanics of doing math, such as being able to recall mathematical facts and/ or difficulty to apply what they know to solve mathematical problems. The survey conducted within the framework of this study is based on types of dyscalculia, which were identified by researcher L. Kosc (Kosc, 1974), namely:

- 1) **Verbal manifestation** of difficulties in verbally denoting mathematical concepts;
- 2) **Practically Gnostic**, in which the systems of counting (calculating) specific and apparent objects or their symbols are disturbed;
- 3) **Dyslexic**, which is based on mathematical sign reading disorders;
- 4) **Graphic**, which manifests itself as a malfunction of mathematical notation and correct representation of geometric figures;
- 5) **Operational**, associated with inability to perform mathematical operations.

Mathematical anxiety is described in this study as the anxiety, tension, or discomfort experienced by many students in performing mathematics or daily activities in a mathematical context (Richardson & Suinn, 1972). Studies show that anxiety impairs the

ability to keep in mind and manipulate information, which is mostly an emotional problem (Ashcraft & Krause, 2007). In this study, questions for measuring math anxiety are based on four factors: test anxiety, physical anxiety, out-of-work behaviour, and social anxiety (Carey *et al.*, 2017).

Dyscalculia and mathematical anxiety are different, but the signs and struggles can overlap. Some students may have both math anxiety and dyscalculia.

Dyscalculia is a mathematics learning difficulty which is a brain-based condition connected to information organization and proceeding. In turn, mathematical anxiety is one of the emotional factors that causes learning difficulties in mathematics.

Based on the above scientific considerations, a questionnaire for teachers was developed (Table 1).

The questionnaire for parents was based on the teachers' questionnaire, asking similar questions that determined the type of dyscalculia or mathematical

anxiety. The questionnaire (in English) for parents is available at: https://ej.uz/Math_parents_En, for teachers: https://ej.uz/Math_teachers_En. In total 33 parents and 67 teachers took part in this study. Information on the respondent included only the age of the children (parents) or the level of education with which the teachers work.

It should be noted that the questionnaires are common for all the age ranges. They include questions that provide answers to questions about the difficulties of learning mathematics for students of any age. Some questionnaire responses are measured on a four-level Likert scale: always, often, sometimes, and never. Only one question is open-ended. As the idea of the problem is based on the need for cooperation between family and teachers, it is very important to use this opportunity, which is the basis of this study. Therefore, it should be noted that this was a case study, and a self-assessment method was used in the study.

Table 1

Questions for teachers to identify math learning disorders

Sections	Appropriate questions
Learning difficulties	Would you be able to identify a case of dyscalculia among your student body? Do you think that the amount of time devoted to the teaching of Maths is enough?
Types of dyscalculia	<ol style="list-style-type: none"> 1. Verbal: Do your pupils know how to articulate their doubts using mathematical language, according to their ages? 2. Verbal and dyslexic: Do your pupils understand the problem statements (spoken or written) and the way to solve them? 3. Graphic: Do your pupils have difficulty in writing numbers clearly or keeping their work neat when solving math problems? 4. Operational: Do your pupils struggle (make mistakes) while solving basic mental arithmetic? 5. What do you think is the main mathematics learning difficulty among your student body? <ul style="list-style-type: none"> • Verbal: Understand and verbalize mathematical concepts; • Operational: Struggle when comparing sizes or quantities; • Operational and practical: Solve arithmetical mental calculations; • Dyslexic: Struggle to identify mathematical signs like + and – and to use them the right way or has trouble understanding number symbols, like making the connection between ‘7’ and the word ‘seven’; • Graphic: Transcript mathematical signs; • Practical: Solve mathematical Problems.
Mathematical anxiety	Do your pupils get easily frustrated, or unnaturally upset while completing a maths problem? Do your pupils present nervousness or agitation before facing an assessable test or task? Are your pupils determined and persistent while completing their Maths tasks?
Ways of overcoming	Please describe how you use inclusive, cooperative, agile or motivational methodologies during your lessons (<i>open question</i>)
Support needed	Do you consider that you have the right tools to help a student who shows learning disabilities or difficulties with Maths? Do you need specific training in emotional skills to help students with Maths anxiety? What are the main resources you need to help this kind of students: <ul style="list-style-type: none"> • Human resources (guidance department, support staff...), • Specific training, • Methodological materials, • Experience exchange, • Other.

Table 2

Mathematical learning disorders from the parents' point of view, answers in % (n =33)

Statements	Very often	Often	Sometimes	Never
Your child is able to understand a mathematical problem, according to his age	35	39	26	0
Your child counts on his fingers	0	4	39	57
Your child shows some difficulties to understand mathematical terms or items	0	17	57	26
Your child makes mistakes in basic calculations (Adding, subtracting, multiplying and dividing)	4	17	74	4
Your child can handle everyday situations that involve mathematical reasoning (Money, time, comparing...)	35	48	9	9
If your child makes it wrong at a mathematical task, does he keep trying?	39	35	22	4
Your child asks you for more help than usual when doing mathematics tasks	17	4	52	26
Your child struggles to understand spatial concepts (Graphics, charts, up, down, right or left)	0	4	52	43
Your child enjoys playing games such as puzzles, chess, checkers, memory games...	17	3	39	13

Results and Discussion

The results of the **parent survey** are summarized in Table 2. They show that, in general, parents are very optimistic about their children's mathematics learning difficulties.

If the answers to the questions are judged by how often they are answered 'very often' or 'often' (in some statements – 'sometimes' or 'never'), then it must be concluded that about one-fifth still have difficulty learning mathematics, which is higher than in the whole world. Educational research shows that learning disabilities affect 10–15% of the population and about 6% of students suffer from dyscalculia. The most problematic area is basic calculations – 21% of respondents indicated a problem of this type. 25% of the respondents show that their children still have mathematical anxiety.

The results of the study also show that learning difficulties often occur between the ages of 9 and 11. Seventy five percent of parents of children in this age group say that their children sometimes count on their fingers. All parents of children aged 6–8 years answered that their children ask for more help than usual when doing mathematics tasks. Results also show that 44% of children aged 12–16 only sometimes can handle everyday situations that involve mathematical reasoning such as money, time, comparing, etc

When analysing the answers to the statements about mathematical anxiety, it is most often observed in the age group 12–16 years (26% of cases). But half of the parents of children aged 6–8 answer in the affirmative that their children speak positively about mathematics at home.

The parents' questionnaire also included the question of whether the parents themselves use a

calculator for small calculations at home. Parents' responses to learning difficulties in mathematics were also analysed after answering this question. The results show that the less often parents use the calculator themselves, the less math learning disabilities their children have. In addition, families where parents do not use a calculator for daily calculations, as children more often play games such as puzzles, chess, checkers, memory games, etc. It shows, that parents' level of math skills (for example, they do not use a calculator in their daily calculations) affects their children's attitudes towards mathematics and their interest in various so-called brain games.

The parents' questionnaire also included a question about the difficulties their child faces in learning mathematics and how they are solved. Most common answers:

- 1) At school, it sometimes needs to be learned by heart to have a pace, but children learn better by understanding the connections;
- 2) Math concepts: nothing is explained individually in the classroom, but a more complex topic should be explained individually;
- 3) There is a lack of time on the part of the teacher to explain the topic more slowly;
- 4) The child often does not understand what the teacher wants from him;
- 5) To achieve good results in mathematics, most often parents attract a private tutor.

The results of the **teacher survey** show that the main mathematics learning difficulties among their student body are:

- 1) Solve mathematical problems – 68%;
- 2) Understand mathematical concepts – 53%;
- 3) Solve arithmetical calculations – 42%;

Table 3

Teachers' answers (%) to questions about types of dyscalculia (n = 67)

Statements	Very often	Often	Some-times	Never
Do your pupils know how to articulate their doubts using mathematical language according to their age?	14	51	33	2
Do your pupils understand the problems statements (spoken or written) and the way to solve them?	16	58	26	0
Do your pupils have difficulty writing numbers clearly or keeping his work neat when solving math problems?	2	25	72	2
Do your pupils struggle (make mistakes) while solving basic mental arithmetic?	5	25	63	7

- 4) Transcript mathematical signs – 39%;
- 5) Struggle to identify math signs like + and – and to use them the right way or has trouble understanding number symbols, like making the connection between ‘7’ and the word ‘seven’ – 19%;
- 6) Struggle when comparing sizes or quantities – 7%.

Seven percent of teachers answered that their students do not have mathematics learning difficulties.

Table 3 provides summarised mathematics teachers answers to statements on types of dyscalculia.

Analysing these results in accordance with the methodology described above, the most problematic type of dyscalculia in Latvia is inability to perform mathematical operations and make calculations (operational and practical). Verbal and dyslexic disorders are less important, but so-called graphic disorders (transcription of mathematical signs) are the least important. According to teachers, mathematics learning difficulties are most common for basic school students. Teachers' responses suggest that mathematical anxiety is equally prevalent at all stages of education.

Summarizing the survey results in line with the conclusions about dyscalculia and mathematical anxiety in the scientific literature, students with dyscalculia often make errors in calculations and perform mathematical activities with difficulty; they do not choose age-appropriate calculation methods and use other problem-solving strategies (such as using fingers). They also have a hard time remembering arithmetic basic facts in long-term memory. Computational difficulties pose significant problems for their academic performance and practical application. Mathematical anxiety affects students' behaviour, for example, some students may be afraid of math lessons or avoid doing homework in math because they are afraid of negative emotions, and so on. Educational research shows that students with high levels of mathematical anxiety can develop

negative attitudes towards mathematics and avoid any math-related activities. Dyscalculia and mathematical anxiety are different, but the signs and struggles can overlap. Some students may have both math anxiety and dyscalculia.

Teachers were asked if they could identify a case of dyscalculia among their students. Only 24.6% of respondents answered in the affirmative, 36.8% answered no, but 38.6% – that they do not know.

Children with dyscalculia need help in organizing and processing information and in everything related to numbers and mathematical concepts and activities. Appropriate teaching methods, appropriate visual and teaching materials, practical and active participation, use of information communication technologies, etc., can greatly facilitate the learning of mathematics (Tübele *at al.*, 2013). Therefore, in the author's opinion, it is important to identify math learning difficulties and opportunities to overcome them, as well as teachers' readiness to do so and the necessary support to activate, motivate, inspire and engage students, to help overcome math learning difficulties and develop math skills. Thus, respondents were also asked to describe how they work with students with dyscalculia, what methods/ methodologies they use. Most common answers are:

- 1) Differentiated / individual approach;
- 2) Additional lessons / summer school;
- 3) Use of reminders (summaries);
- 4) Involving students in games where both numbers and arithmetic operations are written as elements in different form the result of which is that the student remembers these associations when he sees the specific symbol;
- 5) Reformulating the task in simpler words, explaining the rules, allowing the use of a calculator, etc.

More than half of the mathematics teachers surveyed (51%) said that they do not have the right tools (skills, know-how and training) to help a student who experiences (shows) learning disabilities and

difficulties with mathematics. Therefore, the main resources which teachers need to help this kind of students are:

- 1) Methodological materials – 84%;
- 2) Experience exchange – 60%;
- 3) Human resources (guidance department, support staff ...) – 50%;
- 4) Specific training – 37%.

Conclusions

1. The results of the research conducted within the framework of the research show that the difficulties of learning mathematics are assessed similarly by both parents and mathematics teachers, namely, about one-fifth of students have signs of dyscalculia, but 25% – mathematical anxiety.
2. The most pronounced type of dyscalculia in Latvia is an inability to perform mathematical operations and perform calculations (operational and practical). Verbal and dyslexic disorders are less important, but so-called graphic disorders (transcription of mathematical signs) are the

least important. Mathematical anxiety is equally prevalent at all stages of education.

3. Most of the teachers surveyed are unable or unaware of how to determine whether a student has dyscalculia or mathematical anxiety and do not have appropriate tools to help a student with a learning disability / difficulty. Teachers think that methodological materials and exchanges of experience would raise qualifications to help these types of students.
4. Although the self-assessment method was used in the empirical study and the results cannot be generalized, as they are based only on the opinion of the respondents, this study is important because such studies have not been performed in Latvia before.

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MULTIDIMENSIONAL AND MULTIFUNCTIONAL CONTENT OF NATIONAL DEFENCE TRAINING IN LATVIAN SCHOOLS

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Abstract

Continuous changes in the world's political and geographical space are highlighting our national interests in security issues, when thinking about the sustainability of our society and country. Both civic preparedness to act in crisis situations and civic participation in strengthening national security are important. This is a duty of every citizen of our country. Therefore, following the introduction of a comprehensive National defence system in Latvia, the acquisition of the subject of National Defence Training in secondary education programs will be compulsory in Grades 10 and 11 of secondary schools starting from the academic year 2024/2025, but by 31 August 2024, National Defence Training in secondary education will be implemented within the framework of a pilot project. The aim of the research is to analyse the content of the curriculum of the subject National Defence Training from the point of view of curricular didactics, civic education and patriotic upbringing. The research results show that the content of National Defence Training is highly multidimensional and important in the context of the promotion of comprehensive national defence and versatile development of young people as well as in supporting their career development. The concept of comprehensive national defence has four dimensions: military, informational, psychological and civilian. All four of these basic dimensions have been taken into consideration when developing the content of National Defence Training. This has been ensured by integrating the content of military education, civic education and career education into the unified curriculum National Defence Training. The content of military education, civic education and career education has a scientific basis, formed by the results of theoretical and empirical research obtained from the research activities of both Latvian and foreign scientists.

Key words: career education, civic education, curriculum, military education, National Defence Training, patriotic upbringing.

Introduction

Our society lives in a constantly changing environment, which refers also to geopolitical environment. The geopolitical situation in the world is changing and these changes affect Latvia both directly and indirectly. Although we live in a democratic country, Latvian society is well aware of the harsh history of our nation; it follows and is able to critically assess international events near the borders of our country as well as in some more distant areas, and is able to assess the political situation within the country. In order to prepare our society for more or less predictable changes to be faced by the world and also the Baltic countries in the geopolitical space, each individual of our society, including young people, should be prepared for life and action in crisis situations.

On September 24, 2020, the Saeima of the Republic of Latvia approved the National Defence Concept (Valsts aizsardzības koncepcija, 2020), which envisages comprehensive public involvement in the defence of the country in crisis situations.

According to I. Bērziņa and U. Zupa (Bērziņa & Zupa, 2020), the population needs to have a clear vision and understanding of what their role and tasks in national defence are. Considering the survey data, in order to ensure public involvement in the defence of the country, the most important thing is to provide a sufficient level of information and access to specific theoretical and practical knowledge on how everyone

can participate in the national defence, and how to encourage the citizens to participate in the national defence. This means that the goal of comprehensive national defence will be achievable if the Latvian society is ready to defend their country in every way. It is important that the readiness to defend our country is equally explicit to different social groups in society and would not be significantly affected by the language we speak on daily basis although language largely indicates our belonging to a certain culture, gender, age, social affiliation, level of well-being and other important factors.

Until the beginning of 2000, Europe was considered to be a peaceful region, a lot of countries abolished compulsory military service and reduced their military budgets. Following Russia's military action, a number of countries began to look for ways to deal with various crises, thinking about the readiness of the population to defend their country. Compulsory military service in Latvia was abolished in 2006 because there was a position in Europe that the military service was unnecessary. Now a much more modern way would be not to restore compulsory service, but to provide knowledge in a more modern way, involving the public in formal, non-formal military and civic education, with a special focus on patriotic upbringing (Valsts aizsardzības koncepcija, 2020; Valsts aizsardzības mācība skolās ..., 2021). As one of the solutions Latvia has chosen the introduction of National Defence Training in schools.

Several sources (Bērziņa *et al.*, 2020; Informatīvais ziņojums 'Par valsts aizsardzības ...', 2019; Valsts aizsardzības mācība, 2020) show that the formal curriculum for National Defence Training has already been developed, and starting from 2024/2025 it will be implemented in all schools in Latvia. The acquisition of this curriculum will be compulsory in Grades 10 and 11 of secondary education institutions, as well as in the 2nd and 3rd year of studies at vocational secondary education institutions. The curriculum developed so far will be experimentally tested as a part of the pilot project. The introduction of the curriculum National Defence Training in Latvian secondary school education is topical from the point of view of curricular didactics, civic education and patriotic upbringing. The new curriculum has been included in the following areas of study: Health, Safety and Physical Activity, and Social and Civic Learning. The Ministry of Defence of the Republic of Latvia anticipates that during the first year, when this subject will become compulsory, approximately 34,000 young people will participate in the training. Individual approaches are envisaged in order to respect the students and their families' world beliefs, such as religious affiliation and values, beliefs, attitudes, norms of conduct and behaviour resulting from that. The training will take place both at school and in practical training camps; therefore, a mandatory presence in the process of acquiring National Defence Training course will be required. However, distance and correspondence course students will be offered the opportunity to acquire only blocks or modules of theoretical study content, thus gaining the necessary knowledge, skills and competencies (Kuzmina, 2020).

In 2018, 13 Latvian schools applied for the participation in the project, which offered students from Grade 10 of general secondary education institutions and 2nd year students of vocational secondary schools the possibility to master National Defence Training as an optional subject. The schools had to face organizational problems, namely, how to better organize lessons for students who chose this subject and in parallel for those students who did not do that. In June 2019, the first camp was held within the framework of the subject National Defence Training, 67 students from 13 Latvian schools, were involved in the pilot project, took part in the training. The camp took place at the National Armed Forces firing ground 'Lāčusils' in Alūksne county. During this training session the young people practically applied the theoretical knowledge they had acquired in National Defence Training and also improved their field combat and shooting skills (Valsts aizsardzības mācības pilotprojekts ..., 2019). Currently, within the framework of the pilot project, the subject National Defence Training is being experimentally tested by

69 educational institutions throughout Latvia. These are secondary schools, gymnasiums and vocational schools. Such optional study course is also offered in colleges (Valsts aizsardzības mācība skolās ..., 2021).

As there is insufficient number of the conducted research, where researchers focus on the promotion of participation of young people in national defence, and involving them both in formal and non-formal military and civic education already during school years by paying special attention to patriotic upbringing, the aim of the research of the authors of the article was to justify the introduction of National Defence Training in Latvian schools as a topicality of modern education.

Materials and Methods

In 2020, the research on the introduction of National Defence Training in Latvian schools as a topical issue of modern education was launched at Latvia University of Life Sciences and Technologies. In order to be able to carry out empirical research, it is necessary to develop a theoretical basis for the research. Therefore, this article presents the results of the authors' theoretical research, justifying the multidimensional and multifunctional content of National Defence Training from the point of view of curricular didactics, civic education and patriotic upbringing.

In order to justify the introduction of National Defence Training in Latvian schools as a topicality of modern education, theoretical research method was applied: study, analysis and evaluation of scientific literature and normative documents.

Results and Discussion

In the 21st century, the concept – comprehensive or total national defence has been raised, which is related to collective defence, all-encompassing resilience with an emphasis on civil security aspects at the national level. This was decided at the 2016 NATO Warsaw Summit. Based on the results of studies conducted in several countries (Finland, Israel, Singapore, Switzerland), four basic dimensions of the concept of comprehensive national defence have been defined: military, informational, psychological and civilian (Berzina, 2020).

All these dimensions have been included in the content of National Defence Training.

The military dimension is also present in National Defence Training (Bērziņa *et al.*, 2020), which includes *the content of military education*, for example, such topics as: 1) Military topography and orientation; 2) Field combat skills; 3) Formation skills; 4) Safe handling of weapons and shooting with pneumatics, and others.

The inclusion of the content of military education in National Defence Training will also provide a

career education function, which will probably ensure the recruitment of young people in the National Armed Forces of the Republic of Latvia (NAF) and the National Guard, which is one of the national defence issues. Researchers from several countries have published their researches on the involvement of young people in national defence and related issues. For example, in the USA, studies have been conducted (Spoehr & Handy, 2018), and the results show that over time (in the future perspective) there might be a problem of employment in the armed forces, namely, it might be difficult to attract professional labour. There are several reasons for this, such as the restrictions set in various types of regulatory documents, which allow only 29% of young people to get involved in professional national defence, etc. This threatens succession and generational change in the army. In addition, the motivation of young people is important.

The content of military education not only promotes the acquisition of new knowledge and skills in military training, but it also has another task which is to facilitate physical development of young people, including physical endurance. The informative report *On the Implementation of National Defence Training and the Development of the Youth Guard in 2019–2027* (Informatīvais ziņojums 'Par valsts aizsardzības ...', 2019) indicates that with the introduction of new competency-based training content it is necessary to review and update the way how children and young people at all stages of education develop and strengthen the sense of statehood and a sense of belonging to Latvia, how they learn to take responsibility for themselves, their family, community and country, as well as develop not only intellectual but also physical abilities (emphasis added by the author).

Currently **the informative dimension** and **the psychological dimension** (Berzina, 2020), which are justified by changes in the global balance of power structure, as well as by the rapid development of information and communication technologies, are especially relevant. In the 21st century, there is a widespread understanding of the growing importance of information and psychological operations as elements of war. Nowadays, the concept of psychological or information operation is brought forward in matters of national security (Mattis & Hofman, 2005), in the 21st century wars of ideas take place, and our ideas have to compete with the ideas of the enemy (Annis, 2020). Russian military experts define information as a separate dimension of war: the growing importance of non-military instruments in modern warfare has increased (Berzina, 2020). The term hybrid warfare enters both scientific and everyday terminology and vocabulary to describe the specifics of modern security problems. The synthesis

and methods of different tools, both military and non-military, are a key principle in characterizing 'hybrid warfare' and 'hybrid warfare threats' (Mattis & Hoffman, 2005). The list of hybrid tools substantiated by scientists (Treverton *et al.*, 2018, 4) that can be used by enemies in hybrid warfare is relatively extensive: propaganda; fake news; strategic leaks; funding organizations; political parties; organized protest movements; cyber tools (espionage, attacks and manipulation); economic leverage; proxies and unacknowledged war; and paramilitary organizations.

The list is not exhaustive, and all of the above tools can also be used in combination with conventional warfare. In this regard, the Republic of Latvia has developed the Cyber Security Strategy of Latvia 2019–2022 (Latvijas kiberdrošības stratēģija ..., 2019). The aforementioned is the justification for the fact that National Defence Training curriculum (Bērziņa *et al.*, 2020) also includes the topics of communication procedures and cyber security. Innovations in the content of the Youth Guard non-formal education are also expected, new Youth Guard curriculums will be implemented. For example, as a novelty, Cyber Youth Guard classes are planned, which would be offered in parallel with the 2nd level curriculum of youth guard interest education (for students from Grades 7 and 8). These students could later choose to obtain the relevant secondary vocational education (Saldus Technical School already offers a curriculum for cyber security specialists) or higher education in the field of information technology with a specialization in cyber security (Informatīvais ziņojums 'Par valsts aizsardzības ...', 2019). This means opening up new perspectives for young people's career choices and development.

The civilian dimension is expressed in the content of civic education, which is included in the content of National Defence Training, where the focus is on civic activity and participation in the context of national defence. The civic dimension appears both in the goal of National Defence Training and in the content itself. The main goal of this subject is to promote civic awareness and patriotism, as well as to provide an opportunity to acquire basic military skills and abilities, shaping citizens who would be civilly responsible and loyal to Latvia, which is vital for the comprehensive national defence (Valsts aizsardzības mācība, 2020).

Researchers from other countries have concluded that in order to promote the involvement of young people in national defence, it is necessary to be aware of the importance of civic education and offer a well-thought-out content (Kalagbor & Harry, 2018).

The content of civic education is an important tool that helps to develop and strengthen democratic values in society, cultivate civic traditions in society

and promote each individual's sense of belonging to their country, develop a responsible attitude towards society and the state as a whole (Cekste, 2014).

The results of studies carried out in Latvia show that: 1) the civic participation rate in Latvia is 9, which is a low result compared to Sweden (44), Finland (36), Germany (30) and Ireland (22); 2) the involvement of the population in traditional forms of civic participation is decreasing, with a persistently low proportion of the population (17%) believing that they are able to influence the decision-making processes in Latvia is constantly low; 3) young people lack civic participation skills. Around 25% of young people claim to participate regularly (at least 12 times a year) in some social, community or interest activities, incl. only 6% – in public and social activities (participation in non-governmental organizations, charity events, volunteer work, environmental cleaning, etc.). Youth involvement in political activities (participation in party work, political discussions, etc.) is the lowest – only 2% are regularly involved. (Informatīvais ziņojums 'Par Nacionālās identitātes ...', 2019; Spārīte, 2014).

The inclusion of the civic education content into National Defence Training curriculum is a way for the education system to respond to the demand for young people to be engaged in activities relevant to national security that improve each young person's prospects, offer new opportunities and contribute to the sustainable development of society and the country as a whole.

Civic education is not just about national policy and / or international geopolitics. It aims to develop democratic, social, personal and interpersonal competences. The report *Citizenship Education at European Schools (Pilsoniskā izglītība Eiropas skolās, 2017)* provides answers to these and other questions, as well as it includes a comparative overview of the implementation of civic education in Europe. The report covers 28 Member States of the European Union, as well as Bosnia and Herzegovina, the Republic of Macedonia (the former Yugoslavia), Iceland, Liechtenstein, Montenegro, Norway, Serbia, Switzerland and Turkey.

In the United Kingdom, citizenship education aims to provide pupils with the knowledge and skills necessary for active participation for the benefit of society, to acquire knowledge of democracy, the electoral justice system, human rights and responsibilities by teaching to respect different national and religious identities, ethnic groups, promoting critical thinking and developing collaboration skills (Feyfant, 2010). Consequently, the principles and values of Citizenship education prevailing in the United Kingdom are based on the development of abilities, social skills, self-inquiry and personality.

The inclusion of the content of citizenship education into National Defence Training content is a way for the education system to respond to the demand for young people to engage in activities relevant to national security, which improves the prospects of each young person, offers new opportunities and contributes to the sustainable development of society and the country.

The research shows (Cortes, Gomez, & Valle, 2016) that a number of thematic directions can be identified in the content of citizenship education: 1) citizenship education based on the transfer of knowledge to students about the history, geography and policy of the state; 2) citizenship education, which encourages and motivates practical participation in school and public activities; 3) unified citizenship education, which contains the two previous directions, with the aim of providing all opportunities for students to develop their competencies, to form attitudes based on values, by actively fulfilling the duties of an individual and citizen both while studying at school and in the future as an adult. It has been ascertained in the research (Navarro-Medina & Alba-Fernandez, 2015) that this third guideline or direction would be desirable for the implementation of citizenship education in the broadest sense of the concept.

Within the project 'School 2030' a vision (Namsone, 2018; Vērtības un tikumi, 2021), on what educational outcomes should be, has been defined. As a result of the acquisition of competence-based education the benefits of an educated personality in the form of morals, habits and values have been identified, which highlights the importance of the new educational content in schools.

- Virtues: justice, solidarity, compassion, honesty, composure, kindness, courage, moderation, tolerance, wisdom, responsibility, diligence.
- Habits: a) a responsible member of society who goes into details, participates and collaborates to build the society we all want to live; b) a self-confident person who respects and cares for himself and others; c) a creative innovator who introduces innovation, d) an expert in growth, for whom constant and enthusiastic learning has become a habit.
- Values: life, human dignity, freedom, family, marriage, work ethic, nature, culture, Latvian language, Latvian state.

These desirable educational results can also be directly ascribed to the acquisition of the content of the National Defence curriculum.

The role of teachers in citizenship education is emphasized in several publications. There are few studies on the contribution of educators to citizenship education at schools, teaching practices, and experiences that encourage learners to become critical,

creative, patriotic citizens (Sim, Chua, & Krishnasamy, 2017). The implementation of citizenship education requires a set of essential knowledge (although formed from different disciplines), a set of skills (including the ability to gather evidence, recognize types of influence, put forward arguments, take part in debates and speak publicly) and a highly qualified provision of professionals capable of providing creative learning content based on cross-curricular approach (Davies *et al.*, 2014; Wood *et al.*, 2018). Active and open discussions, debates, discussion of problems in an open dialogue on contentious issues contribute to ongoing and future involvement (Flanagan *et al.*, 2010; Hess & McAvoy, 2014; Kahne & Sporte, 2008). Teachers play an important role in enabling pupils / students to express their views in the process of acquiring citizenship education, as well as to allow for individual reflection and cyclical or recursive learning (Biesta, 2011; Parker, Valencia, & Lo, 2017). The role of a teacher is not only relevant in the context of citizenship education, but also in the context of military education and career education, because the content of all these three fields of education is integrated into a joint curriculum – National Defence Training.

The results of theoretical research lead to the conclusion that the content of National Defence Training is distinctly multidimensional and important in the context of comprehensive national defence, promotion of comprehensive development of young people and career development support.

The process of acquiring the content of National Defence Training will have a distinct **educational function**.

In the view of didactics (learning theories), the learning process has several functions, one of them is educational function (Žogla, 2001). In turn, from the point of view of upbringing theories, the study content serves as a means of upbringing in the process of promoting the formation of value and attitude systems, which by its nature is the process interaction between a teacher and a student (Špona, 2001).

One of the most important tasks of National Defence Training is **patriotic upbringing** of young people (Valsts aizsardzības mācība, 2020).

There are several explanations of the concept of patriotism in scientific literature.

Patriotism is an essential individual trait of a personality. Patriotism as a social phenomenon is the basis of the existence and development of any nation and statehood (Takeuchi, 2016).

Patriotism is the moral basis of the country's viability and serves as an important mobilization resource for the development of society, the individual's active civic position and readiness to serve Latvia (Indriksons, 2019).

The results of the researches show (Bērziņa, 2016) that overall the Latvian society has a high level of national pride and patriotism – 74% are proud, 75% are proud that Latvia is an independent country, 71% are patriots of the Latvian State and 86% are patriots of Latvia as it is their place of residence. As many as 70% respondents have expressed readiness to defend the country. However, in case of a military attack, 34% are ready to defend Latvia with weapons; these respondents are ready to sacrifice their lives for the independence of Latvia's statehood.

Several publications (Fedorenko, 2019; Mardonov *et al.*, 2020; Mikriukov, 2009) prove that patriotic and military-patriotic upbringing of younger generations is also relevant in other countries.

Recent events in the world and the geopolitical situation suggest that more attention needs to be paid to the educational environment, which is one of the most important places for the formation of patriotism (Indriksons, 2019). This means that the ecological approach is important in providing an appropriate educational environment.

The implementation of National Defence Training will combine theoretical training with practical training in the field conditions; therefore, on the basis of **the ecological approach**, particular attention will have to be paid to indoor and outdoor environmental contexts.

Conclusions

To ensure that the society is ready for more or less predictable changes in the world's geopolitical space, every individual of the society should be prepared for life and action in crisis situations. One of the most important things is the readiness of the whole society and each of its individuals to protect their country, and its independence. For the comprehensive protection of the country, a legal basis has been developed in Latvia. Several normative documents emphasize that the participation of young people in national defence should be promoted by introducing a new subject – National Defence Training in schools, as well as work with the Youth Guard should be continued, which could be a new shift for the National Guards and professional soldiers in the National Armed Forces of the Republic of Latvia.

The formal content of education for National Defence Training has already been developed and is currently being experimentally tested in several Latvian schools. This subject will be implemented in all Latvian schools starting from the academic year 2024/2025. The acquisition of this curriculum will be compulsory in Grades 10 and 11 of secondary education, as well as in the 2nd and 3rd year of vocational secondary education institutions. The new curriculum includes the following areas of study: Health, Safety

and Physical Activity, and Social and Civic Learning.

The content of National Defence Training is distinctly multidimensional and important in the context of comprehensive national defence, promotion of the comprehensive development of young people and supporting their career development. The concept of comprehensive national defence has four dimensions: military, informational, psychological and civilian. All four of these basic dimensions have been taken into consideration when developing the content of National Defence Training. This has been ensured by integrating the content of military education, civic education and career education into the unified curriculum National Defence Training. The content of military education, civic education

and career education has a scientific basis, formed by the results of theoretical and empirical research obtained from the research activities of both Latvian and foreign scientists. A significant role in the process of acquiring National Defence Training will be given to a teacher, incl. his methodological competence.

The process of mastering the content of National Defence Training will have a distinctly educational function, as one of the tasks of mastering the new subject is to provide patriotic education.

The implementation of National Defence Training shall also be based on an ecological approach when providing an appropriate educational environment, by paying attention to the contexts of indoor and outdoor environments.

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